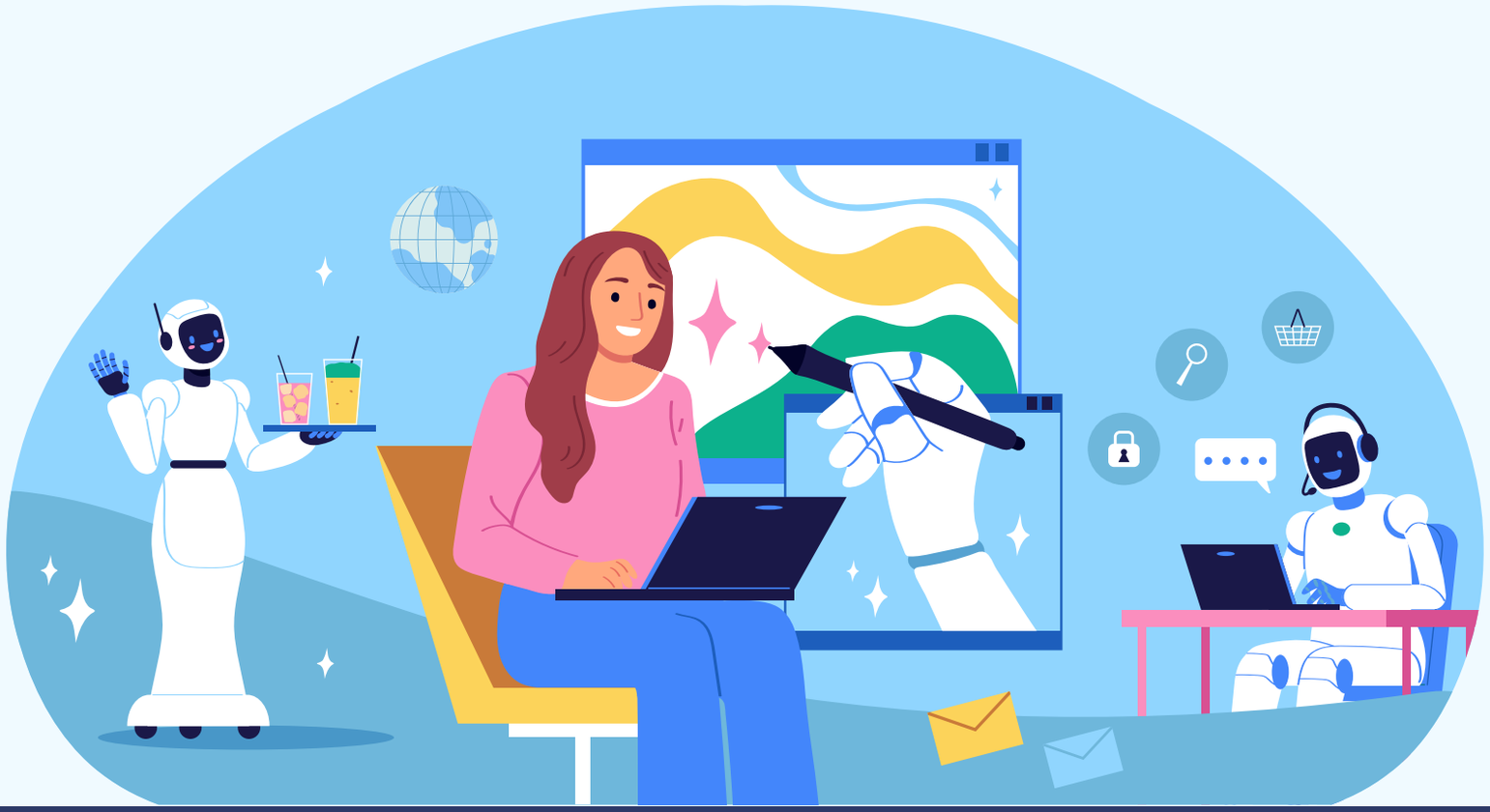
VISIONIAS
INSPIRING INNOVATION

MAINS 365

Summary

SCIENCE & TECHNOLOGY



AHMEDABAD BENGALURU BHOPAL CHANDIGARH DELHI GUWAHATI HYDERABAD JAIPUR JODHPUR LUCKNOW PRAYAGRAJ PUNE RANCHI

VISIONIAS
INSPIRING INNOVATION

SANDHAN

A VisionIAS Personalised Test Series

(An All India GS Prelims Test Series feature
for Smart Revision, Practice and Holistic Preparation
for UPSC Prelims)

- **Extensive Question Bank:**
  Access 20,000+ VisionIAS and UPSC PYQ questions.
- **Current Affairs Integration:**
  Practice with current affairs questions.
- **Personalized Test Creation:**
  Customize tests by subjects and topics.
- **Timed Assessments:**
  Enhance time management with timed tests.
- **Detailed Performance Analysis:**
  Track overall, subject, and topic-level progress.
- **Targeted Recommendations:**
  Receive personalized insights for specific improvement areas.

Admission Open

Scan to know more

CONTENTS

STUDENT NOTE

Dear Students,

To support you, we have **distilled essential information from VisionIAS Mains 365 resources,** renowned for their comprehensive coverage of current affairs.

The summary of **Mains 365 Science & Technology** provides a **comprehensive overview of major scientific and technological developments,** their applications, national and global initiatives, associated challenges and ethical concerns, critical facts and concepts essential for enriching your UPSC Mains .

This summary helps you **revise key topics quickly and effectively.**

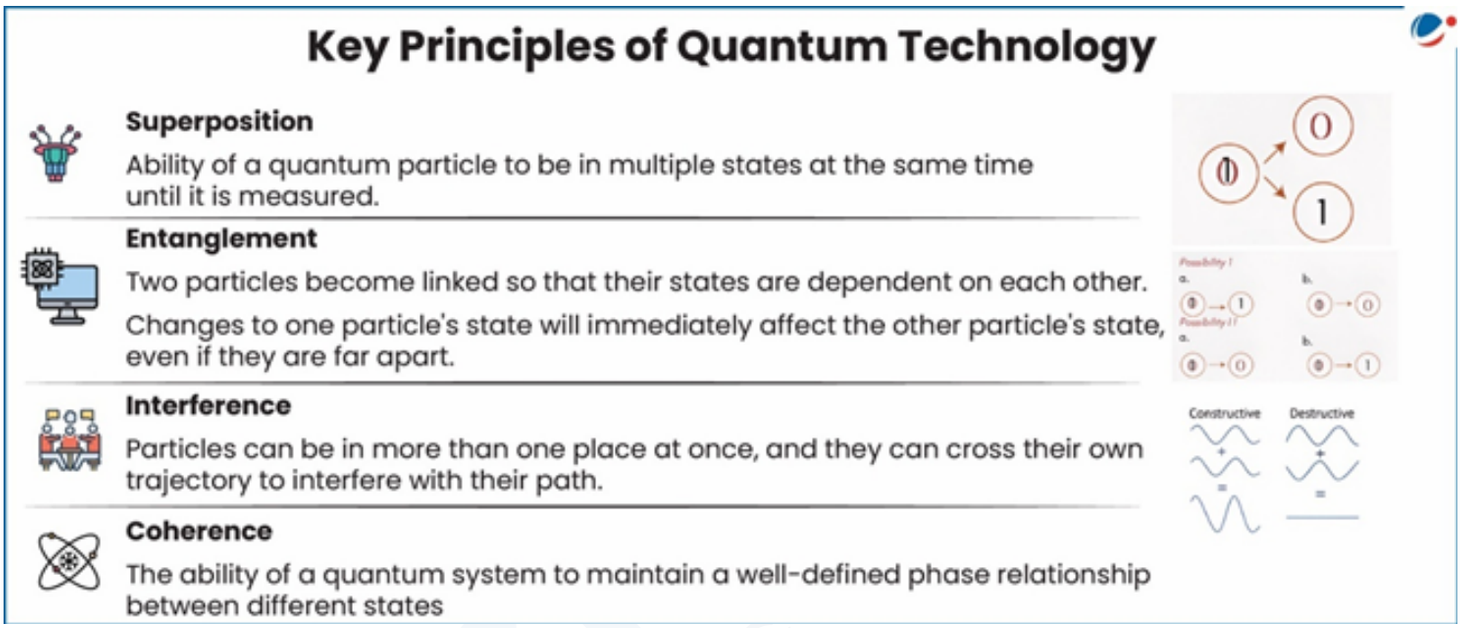
Utilize these insights to enhance your preparation and **ensure a strong performance in the UPSC Mains examination.**

1. IT, COMPUTERS, ROBOTICS

1.1. INTERNATIONAL YEAR OF QUANTUM SCIENCE AND TECHNOLOGY

Why in the News?

UN designated 2025 as the International Year of Quantum Science, marking 100 years since Heisenberg's quantum breakthrough.



Key Applications:

- Secure communication (QKD)
- Advanced sensing/metrology
- Simulations (drug discovery, new vaccines)
- Material design.

Challenges:

- Lack of regulations.
- High infrastructure cost.
- Scalability issues.
- Extreme cooling needs.
- Low R&D spending (only ~0.64% of GDP), and tech gaps.

India's Initiatives in the field of Quantum Technology

- **National Quantum Mission (2023):** To create a vibrant & innovative ecosystem.
- **Quantum Enabled Science & Technology (QuEST):** A research program to build quantum capabilities.
- **Quantum Computing Applications Lab (QCAL):** To accelerate quantum computing-led research.
- **Other initiative:** National Mission on Quantum Technologies & Applications (NMQTA).

Conclusion

- Quantum Technologies aims to boost innovation and build indigenous capabilities. Prioritizing real-world applications such as advanced drug discovery, and precision navigation can ensure quantum technology addresses critical societal and economic needs.

1.2. BRAIN COMPUTER INTERFACES (BCIS)

Why in the news?

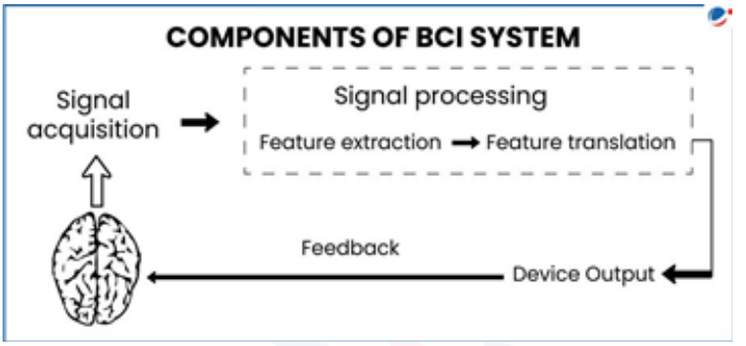
Neuralink's 'Blindsight' BCI implant, granted "breakthrough device" status by the US FDA, aims to restore vision in blind patients.

About Brain-Computer Interface (BCI) implant

- It is a **computer-based system** that acquires brain signals produced by the **Central Nervous System (CNS),** and translates them into commands for a desired action.

Types of BCIs

- **Types:** Invasive (brain implants like Neuralink), Non-invasive (surface detectors like EEG), and Partially Invasive (E.g., Electrocorticography).
- **Applications:** Medical (neurological disorder aid), Mental Wellness, Cognitive Enhancement, and Gaming & Entertainment.



Challenges:

- Technical (interpreting neural patterns, interference),
- Infection risk from invasive BCIs,
- Brain tapping/privacy concerns, stimuli attacks, and
- Ethical issues like " cyborgization" and lack of transparency in clinical trials.

Conclusion

BCI implants hold immense potential for communication, and human-machine interaction. Balancing innovation with ethical safeguards, accessibility, and long-term societal impacts will be key to ensuring BCI technology serves humanity responsibly.

1.3. ORGAN-ON-CHIP (OOC) TECHNOLOGY

Why in the news?

Organ-on-chip technology, expected to be worth around $1.4 billion by 2032, could boost BioE3 (Biotechnology for Economy, Environment, and Employment) goal to personalize medicine.

Organ-on-Chip (OoC) Technology

- It is **human-relevant 3D culture models which,** also known as **'New Approach Methods' (NAMs).**
- It is a **micro-scale system** used for **mimicking the human body environment.**
- **Advantages:** Precision therapeutics, more accurate drug efficacy testing (compared to animal testing), better human physiology simulation (than 2D cultures), and improved research on disease mechanisms.

Four key components:

- **Microfluidics**: This **uses tiny channels to deliver cells** to specific locations.
- **Living Cell Tissues**: It involves arranging specific cell types in the right places to mimic tissue functions.
- **Drug Delivery**: Certain tissues need signals to create a realistic environment for tissue growth.
- **Sensing**: To track and measure data to evaluate the chip's function.

Steps taken for development of Precision Medicine and Organ on chip technology:

- **Amendment of New Drugs and Clinical Trials Rules 2019:** To permit the use of human organs-on-chips.
- **Phenome India Project:** To advance precision medicine.
- **Indian Cancer Genome Atlas (ICGA):** To create a database of cancer data specific to India.

Conclusion

Organ-on-chip technology holds great promise for advancing drug discovery, disease research. With continued investment and innovation, organ-on-chip systems could play transformative role in future healthcare solutions.

1.4. NOBEL PRIZE IN PHYSICS 2024

Why in the News?

Nobel Prize in Physics 2024 has been awarded to **John J. Hopfield and Geoffrey Hinton** for foundational discoveries and inventions that **enable Machine Learning (ML) with Artificial Neural Networks (ANNs)**.

About the Discovery

- **John Hopfield invented Hopfield network**, a type of **recurrent neural network** that can **store and reconstruct information**.
- **Geoffrey Hinton** invented a method (**Boltzmann machine**) that can **independently discover properties in data** and has become **important for large ANNs** now in use.

Artificial Neural Networks (ANNs)

- **Definition:** ANN is a **ML program or model** that makes decisions in a **manner similar to the human brain**.
- **Working: Human brain is the inspiration** behind neural network architecture.
  - Human brain cells, called **neurons**, form a complex, **highly interconnected network** and **send electrical signals** to each other to help humans process information.
  - Similarly, an ANN is made of **artificial neurons or nodes** that work together to solve a problem.

Conclusion

The 2024 Nobel Prizes highlight transformative advancements at the intersection of biology, chemistry, and artificial intelligence.

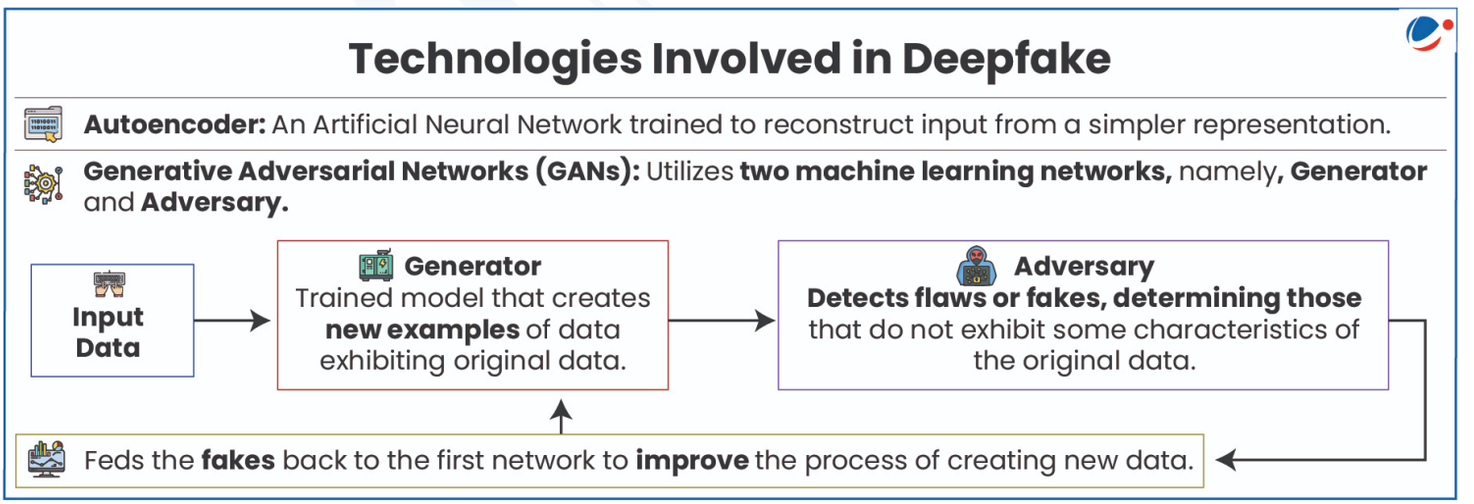
1.5. DEEPFAKES

Why in the News?

Recently, the US enacted **Take It Down Act to** tackle harmful deepfakes online.

What are Deepfakes?

- **AI-manipulated** videos, photos, or audio that appear real.
- **They use "Deep learning"** (a subset of machine learning) to replace faces, alter expressions, or synthesize speech.
- **Potential Applications: Entertainment** (creative effect in movies),**E-commerce** (creating customers likenesses for virtual trial of clothes). **Communication** (Speech synthesis for speaking in another language), etc.



Regulation (India)

- Lacks specific laws, but existing IT Act 2000, IT Rules 2021 (Grievance Appellate Committees), CERT-In advisories, Indian Cyber Crime Coordination Centre (I4C), and National Cyber Crime Reporting Portal offer relief.

Concerns associated with Deepfakes

- National Security Risk (sparking violence, disrupting investigations),
- Eroding Trust in Democracy (misleading political content)
- Victimizing Women (non-consensual pornography), Cyberbullying, Identity Theft etc.

Way Forward on dealing with the issues of Deepfakes

- **Enhanced Regulation:** Focus on proactive action, not just post-incident responses.
- **Technological Advancements:** Massachusetts Institute of Technology (MIT) created a **Detect Fakes website** to help people identify deepfakes by focusing on **small intricate details.**
- **Cyber Literacy: Promote media literacy** and **critical thinking** incorporating **digital trust** to protect all**.**

Conclusion

The Indian legal solution to Deep-Fakes should involve privacy rights, ownership of data, defamation, cybercrime, and intellectual properties protection.

1.6. BIG DATA

Why in the News?

India has joined the UN Committee of Experts on Big Data and Data Science for Official Statistics (UN-CEBD)

About Big Data

- **Definition:** Data whose scale, diversity, and complexity require new architecture, techniques, algorithms, and analytics to manage it and extract value and hidden knowledge from it. It includes
  - **Structured data** (inventory database, list of financial transactions).
  - **Unstructured data** (social posts or videos).
  - **Mixed data sets** (used to train large language models for AI).
- **Applications:** Logistics (E.g., Swiggy), Marketing and Advertising (Netflix, Amazon), Smart Cities, Education, and Earth Sciences.
- **Challenges:** Managing massive data, handling diverse data types, real-time processing, security and privacy concerns (GDPR), and shortage of skilled data scientists.

Conclusion

By adopting scalable infrastructure, AI tools, strong data governance, and upskilling talent, Big Data can become a driver of innovation and strategic growth.

1.7. SUPERCOMPUTERS

Why in the News?

Recently, three Param Rudra Super Computing Systems and a High-Performance Computing (HPC) system for weather and climate research under the National Supercomputing Mission (NSM) were launched.

What is a Supercomputer?

- It is a high-performance computing system that delivers exceptional processing power and computational capacity.
  - Performance is measured in **floating-point operations per second (FLOPS)** instead of million instruction per second (MIPS) used for regular computers.
- India's first was **PARAM 8000 (1991); AIRAWAT** was ranked 75th globally in 2023.
- **Applications:** Cutting Edge Research (**Param Pravega supercomputer**), Governance (Digital India BHASHINI), Weather forecasting(**'Pratyush'**), Internal Security (benami SIM cards), Health and Medicine (**PARAM Shakti**), and Disaster Management (**PARAM Ganga**).
- **Challenges:** Processing & Storage, Energy Demand, Thermal Management, High Costs, Human Resources shortage, and Foreign Dependency (semiconductors).

Way Forward

- **Domestic Manufacturing**: Fast-track India Semiconductor Mission for self-reliant supply chains.
- **R&D Funding**: Increase resources and foster public-private partnerships in HPC.
- **Skilled Workforce**: Establish training programs at C-DAC, IITs, and promote academia-industry collaboration.
- **Green Supercomputing**: Invest in energy-efficient technologies and cooling systems.
- **International Partnerships**: Learn from collaborations like Europe's EuroHPC initiative.

Conclusion

The National Supercomputing Mission strengthens India's global supercomputing position by promoting indigenous development and innovation. With sustained investment, India is set to become a global leader in High-Performance Computing.

1.8. 4D PRINTING

Why in the News?

Indian Researchers developed 4D-Printed Artificial Blood Vessels for Advanced Medical Grafts

About 4D printing

- 4D printing evolves from **3D printing by adding the dimension of time.**
- 4D printed objects **can change shape or function over time in response to environmental stimuli** such as heat, light, or moisture etc.
- **Applications:** Medical (drug delivery, tissue fabrication), Soft Robotics, Aerospace (Nitinol alloy manufacturing), and sensors/flexible electronics.
- **Advantages:** Dynamic Functionality, Material Efficiency, and Complex Design fabrication.
- **Challenges:** Unavailability of technologies (limited research institutes) and Material Limitations (degradation on continuous deformation

Conclusion

4D printing advances 3D printing by enabling dynamic functionality. **Continued material innovation and broader adoption are crucial for unlocking its full potential.**

2. BIOTECHNOLOGY, NANOTECHNOLOGY AND ISSUES RELATING TO INTELLECTUAL PROPERTY RIGHTS

2.1. GENETICALLY MODIFIED ORGANISM (GMO)

Why in the News?

Draft Manufacture, Use, Import, Export, and Storage of Hazardous Micro-Organisms/Genetically Engineered Organisms or Cells (Amendment) Rules, 2024 have been released.

What is Genetically Modified Organism (GMO)?

- **A plant, animal, or microbe** with altered genome (inserted, deleted, or modified sequences) using genetic engineering to **change characteristics.**
- **Purpose:** such as making human insulin, producing fermented beverages and developing pesticide resistance in crop plants.
- **Regulations related to GMO:** Environment Protection Act 1986, Genetic Engineering Appraisal Committee (GEAC), Biological Diversity Act, 2002, Codex Alimentarius Commission, and Cartagena Protocol on Biosafety.
- **How GM Crops are developed:** Gene Gun, Agrobacterium Approach, Electroporation, and Microinjection.
- **GM Crops in India:** Bt Cotton (approved 2002), Bt Brinjal (moratorium 2009), and GM Mustard Crop (DMH-11, not released for commercial cultivation).

Challenges related to GMO

- **Ecological Concerns:** E.g., Bt Corn potentially harms **Monarch butterflies** feeding on wild milkweed.
- **Ethical Concerns:** About inequitable access and benefits of GMOs.
- **Socio-cultural Concerns:** Issues related to **Seed Sovereignty,** impact on **traditional farming** practices.
- **Market Monopoly:** GM crops are controlled by corporations with **IP rights**.
- **Biodiversity Loss:** Use of GM crops may leak GM proteins into the soil, harming beneficial microbes

Conclusion

GMO adoption must be guided by scientific impact assessment, enforced buffer zones for coexistence, increased public R&D in safer seeds, and mandatory labelling to ensure informed choices and sustainability.

2.2. RNA EDITING

Why in the news?

The first successful clinical demonstration of RNA editing in humans was conducted.

About RNA (Ribonucleic acid) Editing

- It is a process that **modifies genetic information on RNA sequences** through insertion, deletion or substitution.
- **Process:**
  - RNA has **four building blocks**: A (Adenine), G (Guanine), U (Uracil), and C (Cytosine).
  - **Adenosine Deaminase Acting on RNA (ADAR) converts adenosine in mRNA to inosine,** which mimics function of guanosine.
  - **Cell detects** Inosine in Adenosine's position, triggering cellular response to correct the mismatch.
  - The process thus **restores mRNA's original function**, and **cell starts making normal proteins.**
- **Challenges in RNA Editing:** Lack of Specificity and Transient nature and nascent stage of development
- **Comparison with DNA editing:** RNA editing is temporary and reversible (safer/flexible), while DNA editing is permanent and carries higher risks of immune reactions.

Conclusion

The first successful clinical demonstration of RNA editing marks a significant milestone in precision medicine. By enabling temporary, reversible modifications to RNA, this technique offers a safer and more flexible alternative to DNA editing.

2.3. NOBEL PRIZE IN MEDICINE 2024

Why in the news?

Nobel Prize in Physiology or Medicine 2024 has been awarded to Victor Ambros and Gary Ruvkun for the discovery of **microRNA** and its role in **post-transcriptional Gene Regulation in 1993.**

About the Discovery

- Till 1993, it was believed that **gene regulation** is limited to **specialised proteins** called **transcription factors**,
- **Discovery revealed** a completely **new principle of gene regulation** that turned out to be essential for multicellular organisms, including humans.
  - **Gene regulation** is the process used to control the timing, location and amount in which genes (out of many genes in a genome) are expressed.
  - **Transcription and Translation:** Transcription (DNA to mRNA) and Translation (mRNA to protein synthesis on ribosomes).

What is miRNA?

- Small non-coding RNA that regulates gene expression by binding to mRNA, preventing translation or degrading it

Significance/Application of microRNA (miRNA):

- Cellular Development (stem cells, tissues), Immune Response, Oncogenesis (cancer, genetic disorders), and Disease Diagnostics (biomarkers).

2.3. MITOCHONDRIAL TRANSPLANTATION

Why in the News?

Experts believe that Mitochondria Transplants, a technique that may create a new field of medicine, can cure diseases and lengthen lives.

About Mitochondrial Transplantation

- Transporting healthy mitochondria to damaged cells, tissues, or organs has recently become a potential therapeutic method for treating mt DNA related diseases and restoring mitochondrial function of diseased cells.
- **Applications: Neural system** (Parkinson, stroke), **Dermatologics** (skin atrophy), **Muscle System** (osteoporosis), **Cardiovascular** (heart failure), **Ophthalmologic** (cataracts), and **Reproduction** (infertility).

Challenges

- Cold Storage (limited active time on ice),
- High-Tech Requirement (specialized equipment, limited to clinical trials),
- Immune Response (risk of rejection),
- Functional Sustainability (long-term compatibility questionable),
- Ethical Concerns (germline gene therapy, genetically modified children).

Conclusion

Mitochondrial transplantation is a promising regenerative therapy for degenerative joint conditions. Future research should focus on standardizing bioengineered mitochondrial transplants to enhance their efficiency and effectiveness.

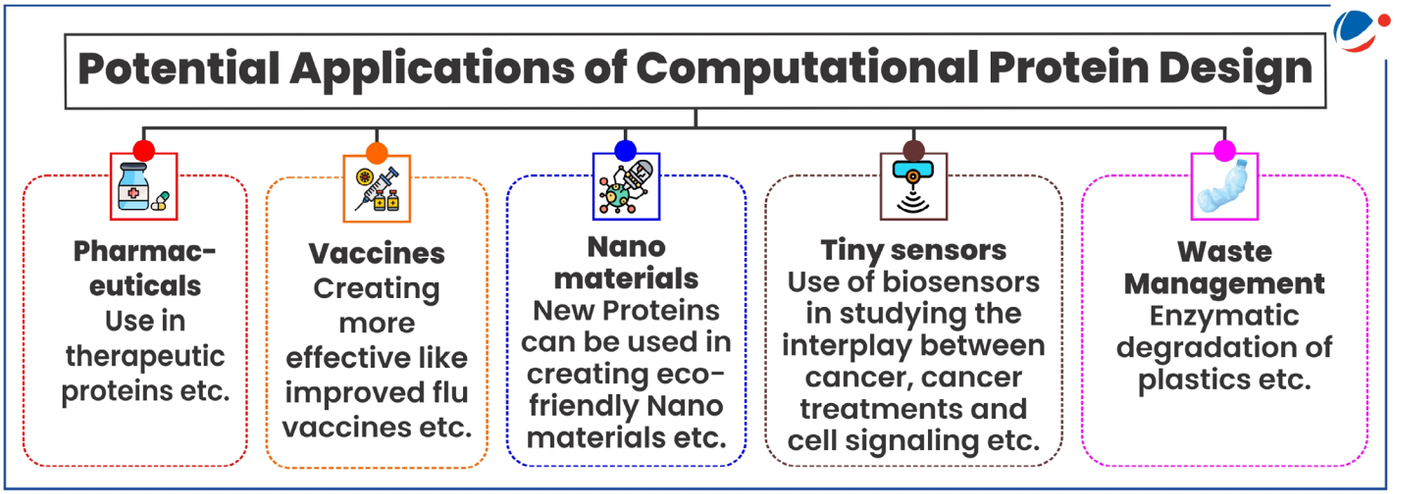
2.4. NOBEL PRIZE IN CHEMISTRY 2024

Why in the News?

2024 Nobel Prize in Chemistry was awarded to **David Baker** for **computational protein design** and jointly to **Demis Hassabis and John Jumper** for **protein structure prediction.**

David Baker's work on computational protein design

- **Computational protein design (CPD)** aims to create new proteins with novel functions or properties not found in nature.
- **David Baker** successfully created new proteins (synthetic proteins), starting with his **first designed protein 'Top7'** in 2003.



Work of Demis Hassabis and John Jumper on protein structure prediction

- **Demis Hassabis and John Jumper** used Artificial Intelligence (AI) to solve a 50-year-old problem of predicting proteins' complex structures i.e., how proteins fold into shapes that determine their functions.
- **Significance of discovery:** Understanding protein shapes is vital for insights into cell function, drug design, antibiotic resistance, enzyme development, and crop resilience etc.

About Proteins

- **Proteins** are one of the **four major types of biomolecules** (the other three being carbohydrates, lipids and nucleic acids).
- They are **biopolymeric structures,** composed of linear chains of **20 naturally occurring amino acids**, linked by peptide bonds.
- **Key-functions:** Structural Support (Actin), Catalysts (enzymes like amylase), Hormones (Insulin), Antibody (IgG), and Transport/Storage (Ferritin, GLUT-4).

2.5. RECOMBINANT PROTEINS (RPS)

Why in the News?

Researchers at Indian Institute of Science (IISc) have developed a **new process for production of recombinant proteins**.

What are Recombinant Proteins (RPs)?

- These are **modified or manipulated proteins encoded by recombinant DNA (rDNA)** for increasing production of proteins, modifying gene sequences, and manufacturing useful commercial products.
  - **rDNA** is **artificially made DNA strand** that is **formed by combination** of two or more DNA molecules.
  - rDNA technology can be used to **combine (or splice) or transfer DNA from different species or to create genes** with new functions.
- **Production**: Mass-produced by growing modified cells (e.g., yeast Pichia pastoris, E. coli) in bioreactors.
- **Applications:** Biotherapeutics (insulin, growth hormones), Vector Vaccines, Agriculture (GM crops, animal feed), and Environment (bioremediation).

Conclusion

The growing need for personalized medicine requires flexible production platforms. There is also a focus on sustainable production practices. Recombinant proteins are expected to continue playing a significant role in various fields.

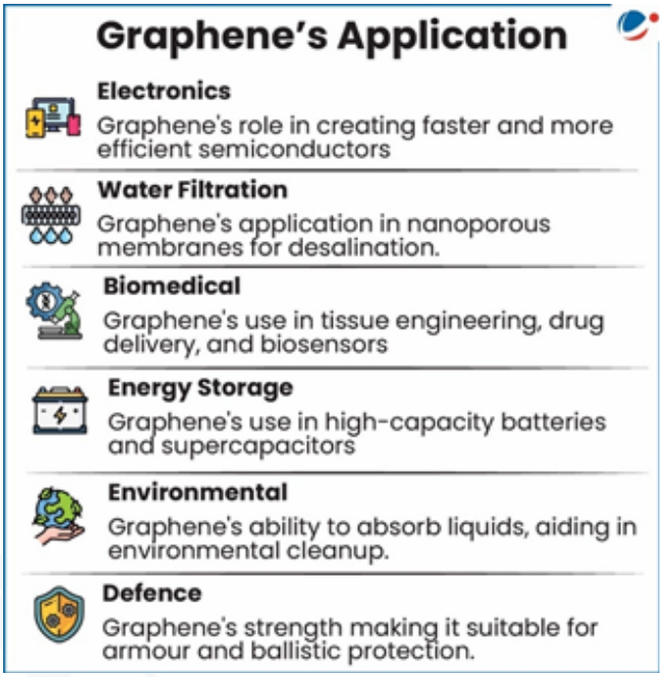
2.6. GRAPHENE

Why in the News?

Recently, MeitY launched **India Graphene Engineering and Innovation Centre** (IGEIC) under the vision of **Viksit Bharat@2047**.

About Graphene

- Discovered in 2004 (Nobel Prize 2010), **an allotrope of carbon**, a single 2D layer of carbon atoms in a hexagonal lattice.
- **Production**: China and Brazil lead in production; India produces ~1/20th of China's output.
- **Properties:** Strength (200x stronger than steel, 6x lighter), Transparency (absorbs 2.3% of light), Impermeability (blocks all gases), and Quantum Effects (Quantum Hall effect).



India's Initiatives to promote Graphene

- **Graphene-Aurora program:** To fill the gap between R&D and commercialization.
- **India Innovation Centre for Graphene (IICG):** Set up in Kerala and funded by MeitY.
- **Research Institution:** IIT Roorkee-incubated **Log 9** has patented a technology for Graphene-based ultracapacitors.

Conclusion

Ongoing research is driving innovations in Graphene composites, hybrid materials, and scalable processing techniques. As these efforts mature, Graphene could become a cornerstone material, enabling breakthroughs in high-performance devices, energy efficiency, and sustainable technologies across multiple sectors.

3. AWARENESS IN THE FIELD OF SPACE

3.1. AXIOM-4 MISSION

Why in the News?

Axiom-4 Mission carrying Indian astronaut Group Captain Shubhanshu Shukla and 3 others successfully returned.

About Axiom-4 (Ax-4) Mission

- It is the **4th private astronaut mission,** to the **International Space Station (ISS),** of private US Company **Axiom Space** in collaboration with **NASA** and **SpaceX.**
- **Key Features:**
  - **Aim**: To "realize the return" to human spaceflight for **India, Poland, and Hungary.**
  - **Ax-4** marks each nation's **first mission to the ISS** in history and with **each nation's first government-sponsored flight in more than 40 years.**
- **Research to be executed by ISRO**: Crop growth in microgravity, Cyanobacteria observation (life support), Space Microalgae (food, fuel), Myogenesis (muscle loss), and Tardigrades (resilience mechanisms).
- **Significance for India:** Valuable inputs for **Gaganyaan Mission** (Shubhanshu Shukla is a selected astronaut), **encourages India's space ecosystem growth** (Bharatiya Antariksh Station), and national pride/inspiration for STEM careers.
  - **Gaganyaan Programme**: India's first Human Space Flight mission (approved 2018) aiming to launch a 3-member crew to 400 km LEO for a 3-day mission.

Major Obstacles for India (Manned Mission):

- **Technological:** Life support system (air, temperature, waste), radiation protection (beyond LEO), spacecraft re-entry/thermal protection, and launch vehicle reliability (human-rated rockets).
- **Logistical:** Higher cost, and rigorous training/selection of astronauts (space-induced psychological issues).

Conclusion

For India, the collaborations under Axiom-4 Mission, not only **accelerates technological learning** ahead of its proposed Gaganyaan mission but also build **critical human capital and infrastructure** for future long-duration spaceflight.

3.2. BHARATIYA ANTARIKSH STATION (BAS)

Why in the News?

Union cabinet has approved the building of first unit of the Bharatiya Antariksh Station by extending the scope of Gaganyaan program.

About Bhartiya Antariksh Station

- BAS is India's **planned space station for scientific research** which will orbit around **400 – 450km above the Earth's surface**
  - It will have **five modules** and will be built in phases.
- **Targets: The first module** (the Base Module) **will be launch in 2028** and BAS will be operationalized by **2035.**
- **Current Status:** BAS is **currently in conceptualization phase**, under which overall architecture, number and types of modules, docking ports etc. are being studied.
- **Other Upcoming Space Stations:** Gateway Space Station (NASA-led, around Moon), and Axiom Station (first commercial space station).
- **Significance of BAS:** Human Spaceflight (testing astronaut safety), Earth Observation (disaster response), Microgravity Research (health issues), Innovation (startup tech testing), and Technological Spin-offs.
- **Challenges:** Low R&D Budget, need for New Technologies (life support, radiation protection), Geopolitics (balancing competition/cooperation), and Astronaut Health (bone loss).

Way Forward

- Funding through international partnerships/private investment, capacity building (ISRO tech for life support), sustainability planning, balancing national interests with global obligations, and international cooperation.

About International Space Station

- It is a large space station that was assembled **in 1998** and operational since **2000.**
- It is maintained in low Earth orbit by a collaboration of five space agencies and their contractors: NASA (United States), Roscosmos (Russia), ESA (Europe), JAXA (Japan), and CSA (Canada
- It is the **largest manmade and habitable** artificial satellite.
- **Altitude:** Installed in the **near-earth orbit** which is about **400 km above the earth.**

3.3. SPACE DOCKING EXPERIMENT

Why in the News?

ISRO, successfully demonstrated the docking and undocking of two small satellites in orbit under the Space Docking Experiment (**SPaDeX).**

What is Space Docking?

- Space docking involves **precise connection of two spacecraft**, allowing those **to operate as a single unit for critical tasks** such as refuelling, repair, and crew exchange.
  - It enables the **construction of cutting-edge facilities like International Space Station** in orbit.

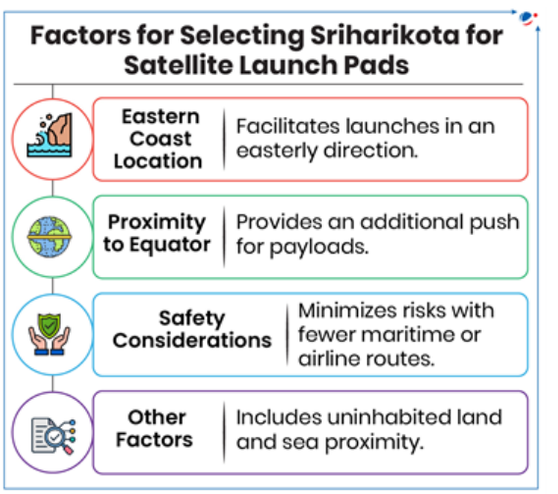
About Space Docking experiment (SPaDeX)

- **About**: Technology demo to master autonomous docking, a capability held only by the US, Russia, and China.
- **Satellites**: Chaser and Target launched by PSLV into different orbits to dock at ~700 km altitude. Docking at ~28,000 km/h to form a single entity.
- **Key Manoeuvres**: Autonomous Rendezvous and Docking, Formation Flying, Remote Operations, and Robotic Arms.
- **Indigenous Technologies**: Inter-satellite communication, GNSS-based Relative Orbit Determination and Propagation (RODP) processor, and docking mechanism/sensors.
- **Significance:** Essential for India's space ambitions (Moon sample return, BAS), Satellite Servicing and Maintenance, Support for Future Space Missions (multiple launches), and other applications (in-space robotics, resource monitoring).
- **Challenges:** Complex Docking (precise coordination, collision risk), Automation (real-time manoeuvres), Sensor Reliability (failure in harsh conditions), Space debris, microgravity, and data transfer/communication stability.

3.4. THIRD LAUNCH PAD

Why in the News?

Union Cabinet approved the establishment of 'Third Launch Pad' (TLP) project at Satish Dhawan Space Centre of ISRO at Srihari Kota, Andhra Pradesh.



About TLP

- **Key Features:** Configured to support Launch of **Next Generation Launch Vehicles (NGLV)** and **Launch Vehicle Mark-3 (LVM3)** with Semi cryogenic stage as well as scaled up configurations of NGLV.
- **Timeline:** To be established within 4 years.
- **Significance:** Capacity augmentation (higher launch frequencies), expanded vision for Indian Space Programme (BAS by 2035, crewed lunar landing by 2040), and future transportation needs.

Existing Launch pads in India

- **First Launch Pad**: It provides launch support for **Polar Satellite Launch Vehicle (PSLV)** and **Small Satellite Launch Vehicle** (**SSLV)**.
- **Second Launch Pad:** It was established primarily for **Geosynchronous Satellite Launch Vehicle (GSLV) & LVM3** and also functions as standby for PSLV.

Conclusion

The expeditious establishment of a Third Launch Pad to cater to a heavier class of Next Generation Launch Vehicles and as a stand by for SLP is highly essential so as to meet the evolving space transportation requirements.

3.5. ENGINE TECHNOLOGY IN SPACE SECTOR

3.5.1. SCRAMJET ENGINE

Why in the News?

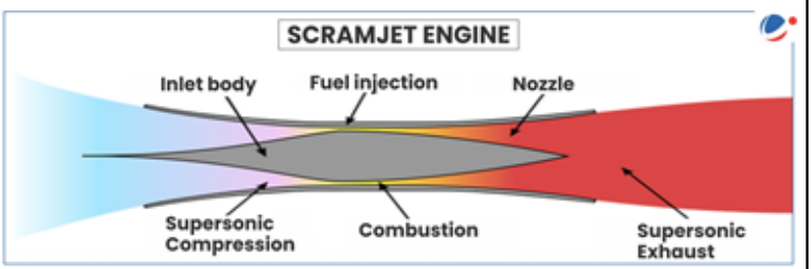
Defence Research and Development Laboratory (DRDL) successfully conducted a 120-seconds ground test of an active-cooled Scramjet combustor for the first time in India.

About Scramjet Engine

- A scramjet engine means a **Supersonic Combusting Ramjet engine**.
  - It is an improvement over the **ramjet engine** as it efficiently operates at **hypersonic speeds** and allows **supersonic combustion**.
    - **Scramjet-powered vehicle** requires an **assisted take off** by a rocket to accelerate it to a speed where it begins to produce thrust.

How does the Scramjet engine work?

- **Air Intake:** Vehicle must already be moving at supersonic speeds (above Mach 3).
- **Compression:** Incoming air is compressed due to the high velocity of the aircraft.
- **Combustion:** Fuel (typically hydrogen) is injected into the compressed air and ignited while maintaining supersonic airflow.



- **Thrust Generation:** The expansion of hot gases produces thrust, propelling the vehicle at hypersonic speeds (based on Newton's third law).

Challenges in Scramjet Development

- High-Energy Fuels,
- High Initial Costs,
- Integration Issues (requires launch mechanism),
- Active Cooling Systems, and Heat-Resistant Materials.

Conclusion

Despite technological challenges, scramjet technology holds immense potential for defense and space applications, enhancing deterrence and reducing space access costs.

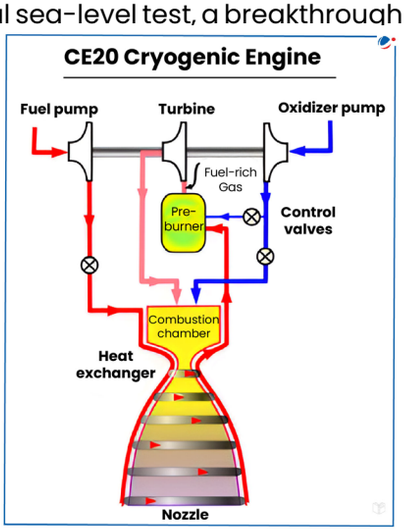
3.5.2. CE20 CRYOGENIC ENGINE

Why in the News?

The Indian Space Research Organisation's CE20 cryogenic engine passed a critical sea-level test, a breakthrough in its propulsion technology.

About CE20

- **Developed by:** The Liquid Propulsion Systems Centre (LPSC), Valiamala, Kerala.
- **Successful Mission:** It has demonstrated its capability by successfully operating in six successive LVM3 missions, including the **Chandrayaan-2, Chandrayaan-3, and two commercial OneWeb missions.**
- **Uses:** Cryogenic engines are the last stage (or upper stage) of a rocket.
  - A Cryogenic engine uses both cryogenic fuel and oxidizer, liquefied at a very low temperature.



How does a cryogenic engine work?

- **The working principle**: The thrust is produced by an **internal combustion/ pressure difference**.
  - Like scramjet, this also follows **Newton's Third law of motion.**

- **Fuel:** The fuel and oxidizer used in a cryogenic engine are liquefied gases, stored at extremely low temperatures.
  - Generally **liquid hydrogen liquefied at -253° Celsius** is used as fuel and liquid **oxygen liquefied at -183° Celsius** is used as oxidizer.

Advantages of cryogenic engine

- **Efficiency and Thrust**: With LOX+LH2 producing maximum energy and lightweight water vapor, resulting in higher performance.
- **Fuel Efficient**: ISRO's PSLV Vikas engine burns 3.4 kg/sec, while cryogenic engines need only 2 kg/sec for the same thrust.
- **Eco-Friendly Technology**: Hydrogen-oxygen combustion emits only steam.
- **Heavy Payloads & Space Missions:** Ideal for heavy payloads and long missions like Gaganyaan.

Challenges in Cryogenic engine technology

Complex Systems (thermal/structural issues), **Thermal Stress** (cracks, blockages), **High Pressure** (superalloys needed), and **Temperature Control** (balancing performance with coolant liner).

Conclusion

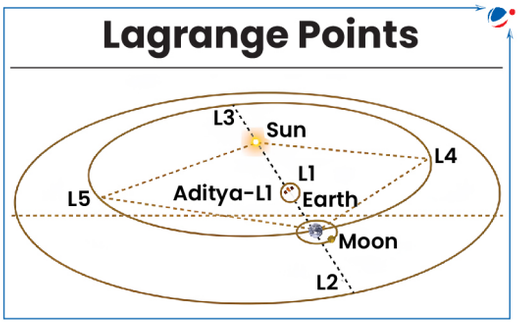
Advancing further, ISRO could explore start fuel ampules like Tri-ethyl-aluminium and Tri-ethyl-boron to enhance ignition reliability and efficiency.

3.6. ADITYA L1

Why in the News?

Aditya-L1 payload captures the first-ever image of a solar flare 'kernel'

About Aditya L1



- **First Indian space mission** to study the Sun (corona, emissions, winds, flares, CMEs).
- **Payload:** Carries 7 payloads (Visible Emission Line Coronagraph (VELC), Solar Ultraviolet Imaging Telescope (SUIT) etc.)
- **Aditya-L1** was inserted in its **halo orbit** in early 2024 around the **Langrange L1** point.
  - At **Lagrange point**, the **gravitational pull** of the **two large bodies** equals the necessary **centripetal force** required for a small object to move with them.
- **For two body gravitational systems**, there are a total five **Lagrange points** denoted as L1, L2, L3, L4 and L5. Out of these L4 and L5 are stable.

What are halo orbits?

- These are **periodic** and **three-dimensional orbits** resulting from an interaction between the **gravitational pull** of the two planetary bodies and **centrifugal force** on a spacecraft.
  - Halo orbits exist in any **3-body system.** E.g., **Earth-Moon orbiting satellite system**.
  - Mainly linked to L1, L2 or L3.
- **Benefits of Halo Orbit:** 5-year mission lifetime, reduced fuel consumption, and unobstructed view of the Sun.

- **Significance of Solar Missions: Forecasting Space Weather** (impacting tech/communications), and **Understanding Cosmic Objects** (Sun study for other stars).
- **Other Solar Missions: Parker Solar Probe** (NASA, first to touch the Sun), **PUNCH** (NASA, solar corona study).
- **Other Solar Observatories: ASO-s (China), Hinode (Japan), SOHO (NASA, ESA, AXA).**

3.7. Hyperspectral Imaging (HSI) Satellites

Why in the News?

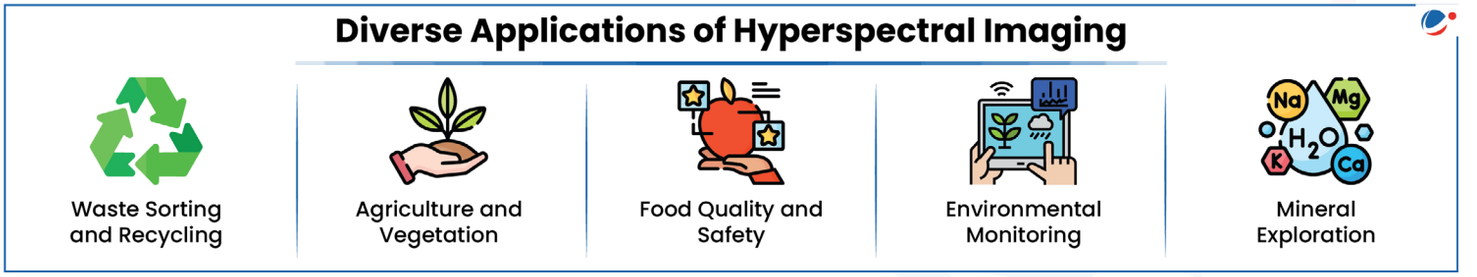
Indian private space-tech company Pixels launched India's first private satellite constellation 'Firefly'.

More on the News

- Firefly is Pixel's flagship Hyperspectral Imaging (HSI) satellite constellation, featuring six of the highest-resolution commercial hyperspectral satellites to date.

About Hyperspectral Imaging (HSI) Satellites

- HSI **analyses a wide spectrum of light** instead of just assigning primary colours (red, green, blue) to each pixel, **effectively spectrally fingerprinting the Earth**.
- While a **typical satellite can identify a forest** from space, **HSI can distinguish between different types of trees** and determine health of each individual tree.



Conclusion

By measuring reflected light across hundreds of narrow, contiguous spectral bands, it identifies patterns and anomalies that traditional sensors miss, enabling reliable analysis in even the most dynamic environments.

3.8. OUTER SPACE GOVERNANCE

Why in the News?

Norway becomes 55th nation to join NASA's Artemis Accords for lunar exploration.

About Artemis Accords

- **Established:** In 2020 by **NASA**/US Department of State, together with **seven other founding member nations** (Australia, Canada, Italy, Japan, Luxembourg, UAE, and UK).
- **Objective:** It sets common **non-binding principles** to govern civil exploration and use of outer space, the moon, Mars, comets, and asteroids, for peaceful purposes.
  - **India is also a signatory** to this Accord.
- **Key Principles:** Peaceful purposes, transparency, non-harmful interference, international standards for interoperability, open data sharing,

Need for Outer Space Governance Reform

- **Space Debris**: 130 million debris pieces exist; no global mechanism for monitoring or removal.
- **Resource Activities**: No agreed framework for exploring and using space resources.
- **Traffic Coordination**: Varying national standards hinder interoperability.
- **Conflict Prevention**: New norms needed to avoid weaponization and conflict in space.
- **Rising Launches**: Satellite numbers growing ~30% yearly (as of 2020).
- **India's Role in Outer Space Governance:**
  - Promote better implementation of existing frameworks, and create Space Domain Awareness (SDA) through international collaborations.

Way Forward (UN Recommendations)

New Treaty (peace, prevent arms race), Debris Removal norms, Traffic Management framework, Resource Use rules, and Inclusiveness (commercial actors, civil society).

3.8.1. SPACE DEBRIS

Why in the News?

SpaceX's Starship rocket explosion dispersed debris over Florida and the Bahamas.

About Space Debris

- **It is defined** as all non-functional, man-made objects, including fragments and elements thereof, in Earth orbit or re-entering into Earth's atmosphere.
- **Space debris** objects larger than **1 cm in size** (Large enough to be capable of causing catastrophic damage) is estimated to be over **1.2 million** (ESA Space Environment Report 2025).
- **Key Sources:** Majority of debris objects originate from on-orbit break-ups as well as on-orbit collisions.
- **Concerns:** Threat to space exploration (catastrophic collisions), Kessler Syndrome (cascading collisions), Risk to life on Earth (uncontrolled re-entry), and Rising cost of maintaining satellites (Collision Avoidance Manoeuvres).

Initiative Taken:

- **Global:** Inter-Agency Debris Coordination Committee (IADC), UN Space Debris Mitigation Guidelines, and Zero Debris Charter (12 countries).
- **Indian:** Debris Free Space Missions (DFSM) 2030, ISRO System for Safe and Sustainable Operations Management (IS4OM), Space Situational Awareness Control Centre (SSACC), and Project Network for Space Object Tracking and Analysis (NETRA).

Conclusion

As the number of satellites and missions grows, proactive measures—such as debris mitigation technologies, international regulations, and responsible space operations—are essential

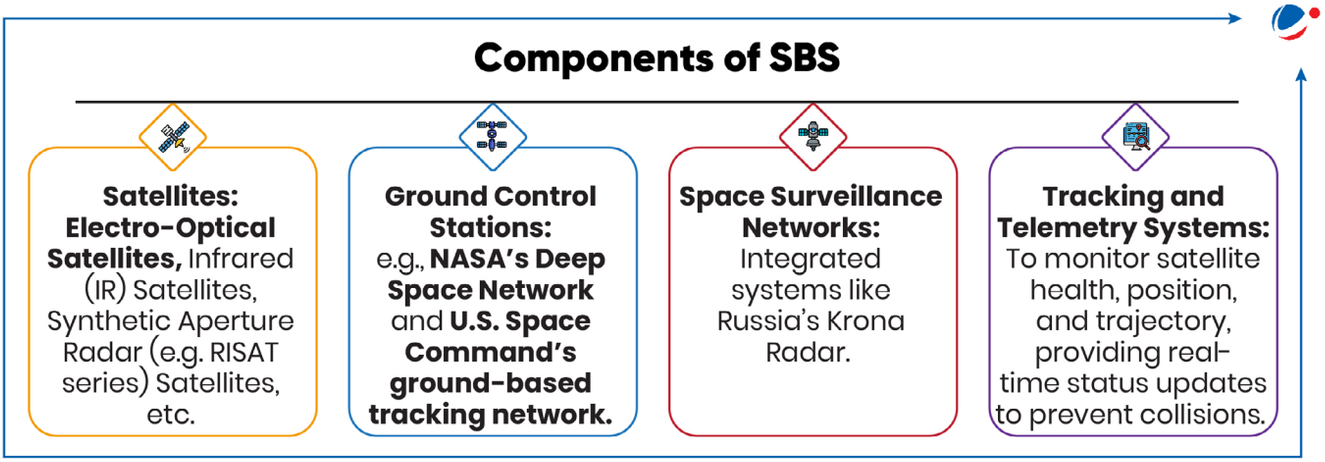
3.8.2. SPACE-BASED SURVEILLANCE

Why in the News?

Cabinet Committee on Security (CCS) has approved the third phase of the Space-based Surveillance (SBS-3) project for better land and maritime domain awareness for civilian and military applications.

About Space-based Surveillance (SBS)

- **It** involves the **use of satellites and other space assets** to monitor and collect data on objects and activities in space and on Earth.
- **India's SBS Projects:** SBS-1 (basic surveillance, 2001), SBS-2 (enhanced maritime awareness, 2013), and SBS-3 (comprehensive land, sea, air coverage with LEO/GEO satellites).
- **Significance:** National Security (missile/military activity), Space Traffic Management (Monitor debris), Asset Protection (ASAT test), Environmental Monitoring, and Scientific Research.
- **Concerns:** Dual-Use Risks (peaceful vs. military), Militarization (arms race), Privacy Issues, and Collision Risks.



Conclusion

To ensure responsible use, global frameworks must promote transparency, prevent misuse, and uphold space as a shared domain for progress.

3.9. NAVIC (NAVIGATION WITH INDIAN CONSTELLATION)

Why in the News?

India used NavIC in Operation Sindoor for combat operations (missile guidance, drone navigation.

About NavIC

- **Developed by ISRO** (erstwhile IRNSS).
- **India is the only developing country** to deploy such a system.
- **Countries with Autonomous Satellite Navigation Systems:** United States (GPS), Russia (GLONASS), European Union (Galileo), and China (BeiDou).
- **Coverage:** 1500 km beyond Indian landmass.
- **Satellite Constellation:** Consists of **7 satellites** and a **network of ground stations** operating 24 x 7.
  - **3 satellites** are placed in **geostationary orbit** and **4** in inclined **geosynchronous orbit.**
  - These satellites are equipped with **dual-band signals (L5 and S-band)**.
  - The **L5 signal** is encrypted for **military use.**
- **Key services: Standard Position Service (SPS)** for civilian users and **Restricted Service (RS)** for strategic users.
- **Strategic Advantages:** Independence from GPS (Kargil War lesson), Encrypted Military Channel, Faster Signal Lock, and Tactical Depth (Indian Ocean Region coverage with NVS series).
- **India's Vision for NavIC:** Hypersonic Weapon Integration and Space Command Network (digital backbone for Defence Space Agency).

Conclusion

By providing reliable, accurate, and secure navigation capabilities independent of foreign systems, NavIC strengthens India's military readiness, enhances civilian applications, and reinforces its position as a major space power.

3.10. SATELLITE INTERNET SERVICES

Why in the News?

IN-SPACe has granted Starlink the licence to commercially operate in India for the next five years.

About Satellite Internet

- **Definition**: Wireless internet through communication satellites, unlike land-based services.
- **Infrastructure**: Space Segment (satellites), Ground Segment (control networks, gateway stations), and User Segment (communication terminals).
- **Prominent Satellite Internet projects**: Project Kuiper (Amazon), OneWeb (Eutelsat), and Qianfan constellation (China).
- **Significance:** Bridges Digital Divide, Disaster Connectivity, Supports Digital Economy, Strategic Autonomy, and Military Use.
- **Issues:** Concerns for internal security (terrorist use of satellite phones), Satellite Latency, Atmospheric changes (ozone depletion), and other issues (weather impact, high cost, space junk).

Conclusion

Prioritizing integration of underserved regions and embracing innovative hybrid models will not only bridge the digital divide but also drive inclusive socio-economic growth and strengthen India's global technological leadership.

3.11. LADAKH AS OBSERVATORY HUB

Why in the news?

Department of Atomic Energy (DAE) inaugurated the **Major Atmospheric Cherenkov Experiment (MACE) Observatory at Hanle, Ladakh.**

More on the News

- Scientists also identify Ladakh as potential site for Martian or Lunar analogue research station.
- Presently, there are **33 analogue research stations** with none being in Indian sub-continent.

About MACE Observatory

- It is largest imaging **Cherenkov telescope in Asia** and **2nd largest in the world.**
- **Objective:** Observe **high-energy gamma rays** to understand the most energetic phenomena in the universe (such as supernovae, black holes, and gamma-ray bursts).

Why Ladakh is chosen for observatory?	Why is Ladakh ideal as Martian/Lunar Analogue?

- **Hanle Valley**: the site is a dry, cold desert with sparse human population.
- **Cloudless skies** and **low atmospheric water vapour** make it one of the best sites in the world for optical, infrared, sub-millimetre, and millimetre wavelengths.
- **Astro Tourism: E.g.** Hanley Dark Sky Reserve (HDSR).
	- **Geomorphological similarities to an early Mars and Moon:**
	  - **Dry, cold, arid desert**, with abundant rocky ground.
	  - **Vast flat land devoid of vegetation**, **dunes**, and drainage networks.
	  - Segregated **ground ice and permafrost**, and rock glaciers.
	- **Geochemical similarities to Martian surface:** Volcanic rocks, saline lakes, and hydrothermal systems.
	- **Exobiological similarities:** Permafrost (evidence of water in past), increased UV and cosmic radiation flux, reduced atmospheric pressure, hot springs (rich in boron).

Conclusion

Identifying Ladakh as a site for research station underscores India's growing role in advancing planetary science and space exploration. Ladakh offers an unparalleled opportunity for testing technologies, studying human factors, and strengthening India's preparedness for ambitious interplanetary missions.

3.12. BLACK HOLES

Why in the News?

Scientists have reported the discovery of gravitational waves from the merger of two black holes that are the biggest to have been observed in such an event.

About Black Holes

- **About:** Regions in space where an **enormous amount of mass** is packed into a **tiny volume** creating a **gravitational pull** so strong that **not even light can escape.**
- They **neither emit nor reflect light**, making them **invisible** to telescopes.
- They are created when **giant stars collapse** and are surrounded by a boundary called an **Event Horizon.**
- **Types:** Stellar-Mass (few to hundreds of Sun's mass), Intermediate-Mass (hundred to hundreds of thousands of Sun's mass), and Supermassive (hundreds of thousands to billions of Sun's mass).
- **Detection:** Through **Accretion disks** (ring of gas and dust surrounding black holes) and **Gravitational waves** (ripples created when very massive objects accelerate through space), etc.
- **Significance of Studying Black Holes:** Testing fundamental theories of Universe like the **General Theory of Relativity** and **Quantum Physics, understanding universe and its origin, gravitational waves,** etc.

Conclusion

As we observe more black hole mergers with gravitational wave detectors like LIGO and Virgo, it becomes ever clearer that black holes exhibit diverse masses and spins, suggesting they may have formed in different ways.

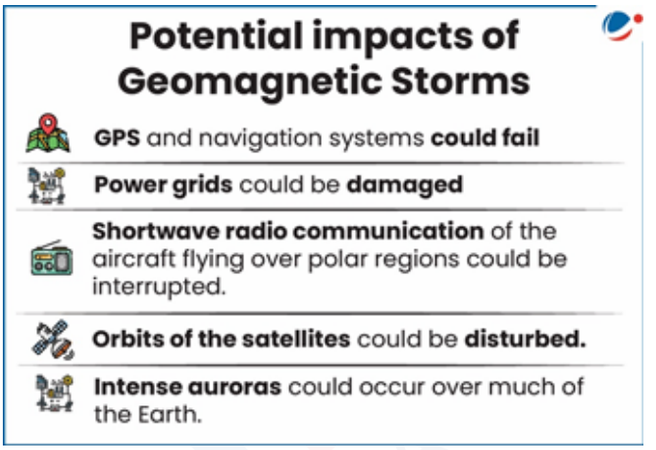
3.13. GEOMAGNETIC STORMS

Why in the News?

After two decades, Earth has been struck by the G-5 Level Geomagnetic Storm.

Geomagnetic Storms

- **Definition:** Geomagnetic or Solar storms are **disturbances in Earth's magnetosphere** (Earth's magnetic field).
- **Classification**: Depending on the intensity, they are classified from **G1** (Minor) **to G5** (extreme).
- **Caused by** charged particles from Sun, triggered by Solar Explosions.
- **Solar Explosions:**
  - **CMEs (Coronal Mass Ejections):** Large expulsions of plasma and magnetic fields from Sun's corona, primary drivers of severe storms. Occur around sunspot groups. Take 1-3 days to reach Earth.
  - **Solar Flares**: Intense bursts of radiation from magnetic energy release associated with sunspots. Largest explosive events, lasting minutes to hours. Travel at speed of light (8 mins to Earth).



Conclusion

As our dependence on technology grows, understanding and forecasting these storms has become more critical. Strengthening early warning systems, investing in resilient infrastructure, and fostering global collaboration will be essential to mitigate their impacts and safeguard modern society.

3.14. METEORITE

Why in the News?

Scientists have confirmed a meteorite fall in a village in Beed (Maharashtra).

Difference between Meteoroid, Meteor and Meteorite

Stage	Meteoroid (In Space)	Meteor (In Atmosphere)	Meteorite (On Earth)
Definition	Space rocks broken from larger bodies.	Meteoroids burning in atmosphere ("shooting stars").	Meteoroids that reach Earth's surface.
Features	Rocky/metallic, smaller than asteroids.	High-speed entry, burn up, meteor showers.	Stony, iron, or stony-iron types; impact craters.
Examples	From planets, asteroids, comets.	Seen as streaks of light.	Lonar Lake crater, dark burned surfaces.

- **Significance of Study:** Understanding Solar Systems (past records), Geological composition (geochemistry, mineral composition), and Evolution of terrestrial planets/origin of life.
- **Exploration Initiatives:** NASA 's All Sky Fireball Network and Canada's CMOR (Canadian Meteor Orbit Radar).

Conclusion

By studying these celestial objects, scientists can deepen our understanding of planetary formation, geochemical processes, and cosmic history.

VISIONIAS
INSPIRING INNOVATION

Vision Publication

IGNITING PASSION FOR KNOWLEDGE

In a world where knowledge is the gateway to countless opportunities, having access to the right resources is essential. **VisionIAS** proudly presents Vision Publication, your trusted source for simplified, high-quality, and comprehensive learning materials. Whether you're feeding your curiosity or preparing for competitive exams, Vision Publication equips you with the knowledge and insights to excel.

Objectives of Vision Publication

Empower Learners: Deliver comprehensive study materials that cover a wide range of subjects, including but not limited to the UPSC exam.

Foster In-Depth Understanding: Provide subject-specific books that explore History, Geography, Polity, Economics, Science, and more.

Stay Current: Offer up-to-date resources, including current affairs magazines and topic-specific compilations that keep you informed.

Enhance Exam Preparedness: Equip readers with exam insights, including trend analysis, expert strategies, and practical tips.

Support Last-Minute Prep: Provide quick notes, last-minute guides, and comprehensive revision tools to ensure you're well-prepared.

Promote Intellectual Expression: Offer a platform for authors to publish their works, contributing to a diverse and vibrant body of knowledge.

Who is Vision Publication for?

Designed for lifelong learners, UPSC aspirants, educators, and anyone passionate about intellectual growth and academic excellence.

Key Elements of Vision Publication

Comprehensive Study Guides: Books that cover a broad spectrum of subjects, ensuring thorough exploration and understanding.

Expertly Crafted Content: Each publication undergoes meticulous review to maintain the highest standards of quality and accuracy.

Interactive Learning: Engaging formats and practical examples that make complex subjects accessible and enjoyable.

Cutting-Edge Insights: Latest trends, analyses, and strategies to help you stay ahead, whether in competitive exams or general knowledge pursuits.

Accessible Knowledge: Available in print format, our materials are designed to be easily accessible to all learners.

Author Collaboration: A platform for aspiring and established authors to publish their works, enriching the learning experience with diverse perspectives.

"Education is the most powerful weapon which you can use to change the world."
– Nelson Mandela

Scan the QR code to explore our collection and start your journey towards success.

AHMEDABAD | BENGALURU | BHOPAL | CHANDIGARH | DELHI | GUWAHATI | HYDERABAD | JAIPUR | JODHPUR | LUCKNOW | PRAYAGRAJ | PUNE | RANCHI

4. HEALTH

4.1. TRANS-FAT ELIMINATION

Why in the News?

World Health Organisation (WHO) has published the fifth milestone report on progress towards global trans-fat elimination covering the period from 2018–2023.

Key Finding of the report

- **The policies** have improved the food environment for **46% (it was only 6% in 2018) of the world's population.**
- **WHO's ambitious target** to fully eliminate trans-fat from the global food supply by the end of 2023 has **not been fully met.**

About Fat

- **Fatty acids,** which are the building blocks of fat, are long chains of **carbon and hydrogen atoms.**
- **Essential fatty acids** are those needed by the **human body** that can only be obtained through food.
- **Different Kinds of Fat:** Unsaturated fats (good, lower calories), Saturated fats (animal products), and Trans fats (worst type, industrially produced partially hydrogenated oil - PHO).

About Trans-fat (or Trans-fatty acids (TFA))

- **They are considered** as the worst type of fats (bad fat).
- **Types of Trans-fat**
  - **Natural** (ruminant trans fats) and are not considered harmful.
  - **Artificial:** They are formed in an industrial process that adds **hydrogen** to **vegetable oil**, converting the liquid into a solid and resulting in partially hydrogenated oil (PHO).
- **Health Impacts (Trans-fat):** Raises bad cholesterol, lowers good cholesterol, linked to inflammation, overweight/obesity, high BP, diabetes.
- **Steps Taken to Regulate:** FSSAI initiatives (Trans-fat free logo, Heart Attack Rewind, Eat Right India Movement, capped TFA at 2% by 2022), and WHO's REPLACE action framework (2018).
- **Challenges in Eliminating Trans fat**: High demand in food industry (cheaper alternatives), poor enforcement, and consumer preferences for processed food.

Way Forward to reduce use of Trans fats

- **Policies**: Countries must strengthen enforcement mechanisms to qualify for the WHO Validation Certificate.
- **Healthier Alternative**: replaced with oils rich in **Polyunsaturated Fatty Acids (PUFA)**. E.g. safflower, corn, sunflower, soybean, peanut etc.
- **Awareness and nudge:** like warnings and images used in cigarette packets.

Conclusion

Eliminating trans fats is vital to reduce heart disease and improve public health. With strong regulations, industry reform, and public awareness, a trans fat-free world is an achievable and urgent goal.

4.2. OBESITY

Why in the News?

PM stated 1 in 8 people globally live with obesity; cases among children/adolescents quadrupled.

Status of obesity in India as per NFHS-5 (2019-2021)

- Overall, **24% of women** and **23% of men** are overweight or obese.
- **Child (under 5 years**) overweight rates **increased from 2.1% to 3.4% between 2015-16 and 2019-21.**

About Obesity

- **Definition**: Abnormal/excessive fat accumulation risking health (WHO). BMI 30+ is obese.
- **Factors Driving Obesity:** High-Calorie/Low-Nutrient Diets, Sedentary Lifestyles, and Use of Genetically modified crops.
- **India's Strategic Framework:** POSHAN Abhiyaan, Fit India Movement, National Programme for Prevention and Control of NCDs, Eat Right India, and RUCO (Repurpose Used Cooking Oil) Initiative.

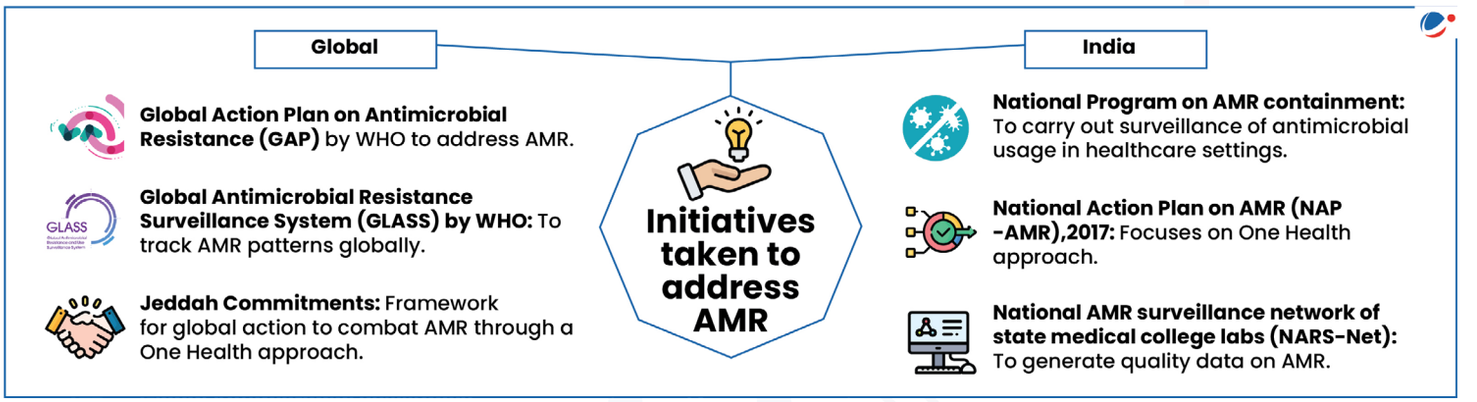
4.3. ANTI-MICROBIAL RESISTANCE (AMR)

Why in the News?

UNGA High-Level Meeting on AMR approved political declaration to reduce human deaths from bacterial AMR by 10% by 2030, calling for $100 million in funding.

What is AMR?

- It is a **condition when microorganisms** such as bacteria, viruses, fungi, and parasites change in ways that render the **medications** used to cure the infections they cause ineffective.
- **Scenario of AMR:** ~39 million deaths estimated from antibiotic-resistant infections by **2050,** with **2 million annual deaths** projected in India alone. (The Lancet study).
- **Major Factors: Pharmaceutical Manufacturing** (industrial waste), **Agriculture** (antibiotic overuse), **Healthcare Facilities** (improper drug disposal), and **Waste Management** (landfill leachate).



Why AMR is a Global Health threat?

- **Economic cost** ($1 trillion by 2050), **modern medicine** gains at risk, **impact on vulnerable populations,** and limited R&D for alternatives.

Way Forward

WHO Guidance on Wastewater and Solid Waste Management for Antibiotic Manufacturing:

- **Regulations**: Implement Environment (Protection) Amendment Rules, 2019, which impose stringent limits on residues of 121 antibiotics in treated effluents from drug production units.
- **Agriculture Operations**: organic farming can be promoted to limit the use of antibiotics.
- **Promoting Responsible Use**: Implement antibiotic stewardship programs for responsible antibiotic use.

4.4. ZOONOTIC DISEASES

Why in the News?

India's Integrated Disease Surveillance Programme (IDSP), 2018–2023 reported Zoonotic disease outbreaks.

Key-findings

- **Outbreaks reported**:8.3% were zoonotic, with a median of **seven monthly zoonotic outbreaks**.
  - **Japanese encephalitis accounted for 29.5% of zoonotic outbreaks**, followed by **leptospirosis** and scrub typhus.
- **Northeast region** contributed to around **one-third** of zoonotic disease outbreaks, followed by Southern region.

About Zoonotic Diseases

- **Definition:** Naturally transmitted between vertebrate animals and people (WHO).
- Zoonotic pathogens may be **bacterial, viral or parasitic**, and can spread to humans.
- Globally, **60% of reported emerging infectious diseases globally are zoonoses**.
- According to 1st State of the World's Animal Health Report, infectious animal diseases are expanding into **new geographical areas**, with nearly **47% having zoonotic potential.**
- **Factors for Disease Emergence:** Wildlife/Forest Encroachment, Poor Sanitation, Deforestation & Animal Trade, Environmental changes, Genetic Mutations, Air Pollution, and Population Increase.

- **Initiatives taken to reduce Zoonotic Disease:** Integrated Disease Surveillance Programme (IDSP) (monitors 6 zoonotic diseases: Anthrax, CCHF, Rabies, KFD, Leptospirosis, Scrub typhus), National One Health Programme, and Disease Specific Programs (Rabies, Leptospirosis, Snakebite Envenoming).

Conclusion

Strengthening disease-specific surveillance, especially in hotspot regions, is essential for timely, evidence-based interventions.

4.5. DRUG QUALITY IN INDIA

Why in the news?

CDSCO directed recall of 49 medicines for "not of standard quality."

Regulation of drugs in India

- **CDSCO:** It regulates **quality, safety and efficacy of Drugs, Medical Device and Cosmetics** in India **Drugs & Cosmetics Act, 1940** and Drugs and Cosmetics Rules, 1945.
- **Drugs and Cosmetics Act (DCA), 1940:** It regulates import, manufacturing, sale and distribution of drugs in India.
- **State Drug Regulatory Authorities (SDRAs):** Responsible for licensing of manufacturing establishments, surveillance over sale of spurious drugs.
- **National Pharmaceutical Pricing Authority (NPPA):** It revises the prices of controlled bulk drugs and also monitors the availability of drugs, identifies shortages.

Issues with drug quality in India

- **State-Level Authorities (SLAs):** SLAs (ill-equipped labs, paucity of inspectors).
- **Non-Compliance** (only 2,000/10,500 manufacturing units WHO-GMP compliant in 2023).
- **Information Asymmetry:** Centralised record keeping, absence of national database of manufacturers etc.
- **Limited reach** of Pharmacovigilance.

Measures taken to ensure quality of Drugs

- **'Strengthening of States' Drug Regulatory System (SSDRS).**
- **Amendment to DCA 1940 (stringent penalties).**
- **Amendments to Drugs and Cosmetics Rules ,1945 (mandatory inspection).**
- **Revamping Pharmaceuticals Technology Upgradation Assistance Scheme (PTUAS).**

Conclusion

Improving drug regulation in India requires uniform standards, stronger **CDSCO-SDRA** collaboration, better infrastructure, financial autonomy, and use of digital tools to enhance drug quality and patient safety.

4.6. FIXED DOSE COMBINATION DRUGS

Why in the News?

CDSCO prohibited the manufacture, sale or distribution of 35 **fixed-dose combination (FDC)** medicines**.**

What are FDCs Drugs?

- **Definition**: FDCs refer to **products containing two or more active ingredients** also referred as cocktail drugs used for a particular indication (as per **Drugs & Cosmetics Rule 1945).**
  - **Active Ingredient** is the biologically active component of a drug product (tablet, capsule, cream, injectable) that produces the intended effects.
- **Mostly FDCs** are in **combinations** of **cough, cold, and fever preparations**; **antimicrobials; vitamins and minerals** etc.
- **Impact of Ban:** Pharmaceutical Industry (revenue loss, increased compliance cost), Public Health (shift to better alternatives), and Healthcare System (disruption in medicine availability).

Rationale for Usage of FDCs	Issues associated with FDCs
◆ **Enhanced efficacy**. ◆ Cost-effectiveness. ◆ **Reduced pill burden** and patient compliance. ◆ They have a **pharmacokinetic** advantage. ◆ **Pharmacokinetics** is defined as the study of absorption, distribution, metabolism, and excretion of drugs by the body.	◆ **Lack of individual dose flexibility** may not be suitable for all patients. ◆ **Unapproved and Banned FDCs** accessible in countries like India. ◆ **Increased risk of Anti-microbial Resistance (AMR)** due to potential overuse. ◆ **Ethical concern as** there is no ban on same drugs being exported to African or SAARC countries.

Conclusion

Strong punitive action (Mashelkar Committee), Evidence-Driven Authorization, Surveillance Systems, and Export Control Stringency, Periodic surveys of manufacturers and retailers can help assess existing challenges.

4.7. CHIMERIC ANTIGEN RECEPTOR (CAR) T-CELL THERAPY

Why in the News?

India's first homegrown gene therapy (CAR-T cell therapy) for cancer has been launched.

About CAR T-cell therapy

- **It modifies immune cells, specifically T-cells,** by turning them into potent cancer fighters known as CAR-T cells.
  - **T-cells are special cells** (types of white blood cells) whose primary function is cytotoxic, meaning killing other cells.
- **T-cells taken from patient**, engineered with a man-made receptor (CAR) to recognize cancer cells, then re-infused.
- **Benefits:** Extended cancer treatment, potential for complete cure, short treatment time, rapid recovery.
- **Challenges:** Cancer-specific therapy (not universal), negative effects on nervous system, and infection risk.

Conclusion

Future development direction aims to expand the range of applications, improve the therapeutic effects, reduce the serious side effects and lower the cost of treatment.

4.8. ORAL REHYDRATION THERAPY (ORT)

Why in the News?

Richard Cash, instrumental in ORT development, died.

About Oral Rehydration Therapy (ORT).

- **ORT** is the **administration of appropriate solutions** (glucose, sodium chloride, sodium bicarbonate, and potassium chloride or citrate) by mouth to prevent or correct dehydration.
- **ORT consists of**:
  - **Rehydration**: Water and electrolytes are administered to replace losses.
  - **Maintenance fluid therapy** to take care of ongoing losses once rehydration is achieved (along with appropriate nutrition).
- **Treatment for: Diarrhoea** (reduced child mortality by two-thirds since 1990) and **Cholera** (reduced mortality from >50% to <0.2%).
- **Efficacy in Adults**: The patients receiving the oral solution required **80% less intravenous fluids** for cure in comparison to other techniques.

How ORT works?

- ORT works because of the **molecular mechanisms that govern sugar and sodium absorption inside the gut.**
- The cells that make up the lining of the gut have **special receptors on their surfaces that allow them to actively absorb sugar molecules.**
- The increase in sugar and sodium inside the cells leads to **increased absorption of water and chloride ions.**

Initiatives:

- **Indian Initiatives:** National Oral Rehydration Therapy Programme (1985), National Health Mission (NHM), and STOP Diarrhoea Campaign.
- **Global Initiatives:** WHO/UNICEF recommended (ORS + zinc), Global Task Force on Cholera Control (GTFCC) Roadmap 2030, and GAVI, the Vaccine Alliance.

4.9. PANDEMIC AGREEMENT

Why in the News?

World Health Assembly (WHA) Adopted World's First Pandemic Agreement.

Key Highlights of the Agreement

- **Pandemic Prevention**: Aligned with International Health Regulations (IHR, 2005) to manage global disease spread.
- **Global Supply Chain**: Ensures access to health products during health emergencies.
- **Sustainable Financing**: IHR's Financial Mechanism to support implementation.
- **Pathogen Access and Benefit Sharing (PABS) System** (timely data sharing, pharma firms give WHO access to 20% real-time production).
- **Enforcement**: Agreement opens for ratification post-PABS; enforced after 60 ratifications.

Existing Framework for Epidemic/Pandemic Management

- **'Public Health and Sanitation'** under Entry 6 of the State list (Seventh Schedule).
- **Entry 29 of Concurrent List (infectious diseases)**
- **International Health Regulation (2005)** for handling public health emergencies.
- **EDA 1897** is main legislation on subject matter.

Conclusion

Agreement's adoption follows three years of intensive negotiation launched due to gaps and inequities identified in national and global COVID-19 response. Next steps include negotiations on Pathogen Access and Benefits Sharing system.

4.10. DISEASES

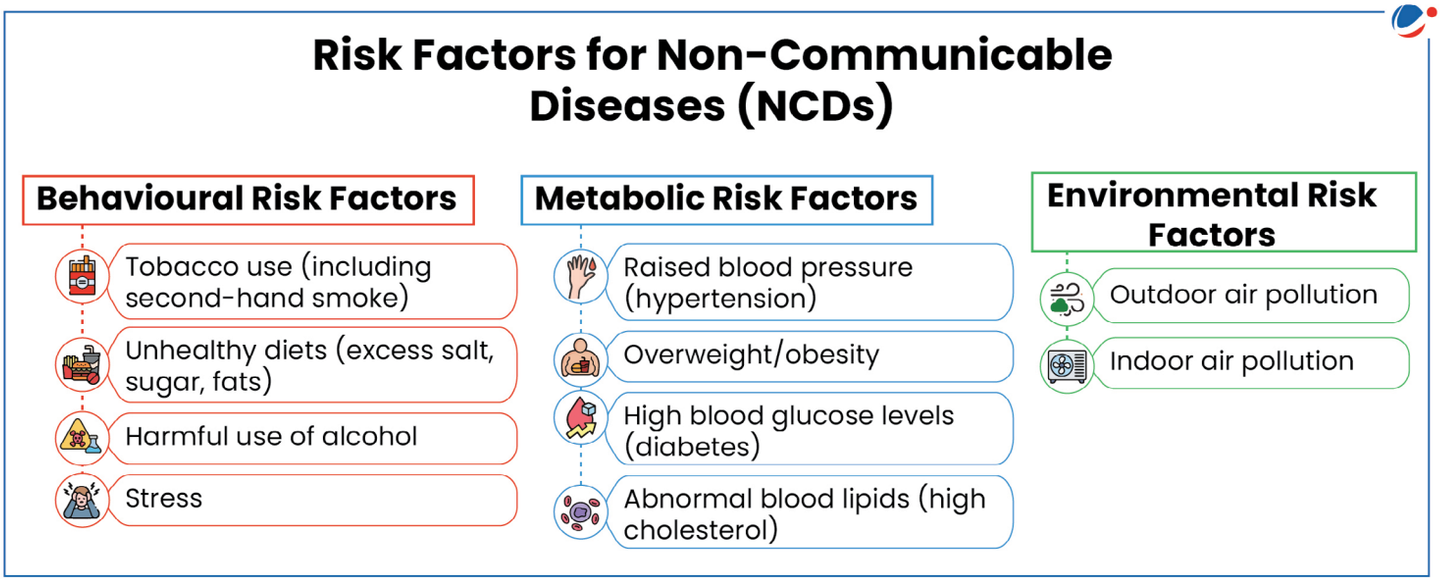
4.10.1. NON-COMMUNICABLE DISEASES (NCD)

Why in the News?

Ministry of Health & Family Welfare launched the Intensified Special NCD Screening Drive.

About Non-Communicable Diseases (NCDs)

- **NCDs** are **chronic diseases that are not transmissible** from one person to another.
- **Types**: Cardiovascular diseases, cancers, chronic respiratory diseases and diabetes.
- **Scenario:** NCDs accounts for **74% of all deaths globally** and **63%** of all deaths in India.



Initiatives for Controlling NCDs

- **Global:** SDG target 3.4 (1/3rd NCD mortality reduction by 2030), WHO Global Action Plan (2023-2030).
- **India:** Affordable Medicines and Reliable Implants for Treatment (AMRIT), National Tobacco Control Programme (NTCP), and National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS).

Recommendations for Prevention and Control of NCDs:

- **NCD Management**: Early detection, treatment, and palliative care via primary healthcare.
- **Digital Health**: Invest in low-cost tools (e.g., chatbots).
- **Fiscal Measures**: Use taxes on tobacco, salt, and sugar to reduce risk factors.
- **Life-Course Approach**: Integrate NCD policies with labour, social protection, and long-term care reforms.

Conclusion

Non-communicable diseases are a major global health challenge but largely preventable through lifestyle changes, consuming food low in Glycemic Index, early detection, and strong public health measures. A collaborative approach is essential to reduce their impact and ensure better health outcomes.

4.10.2. TUBERCULOSIS (TB)

Why in the News?

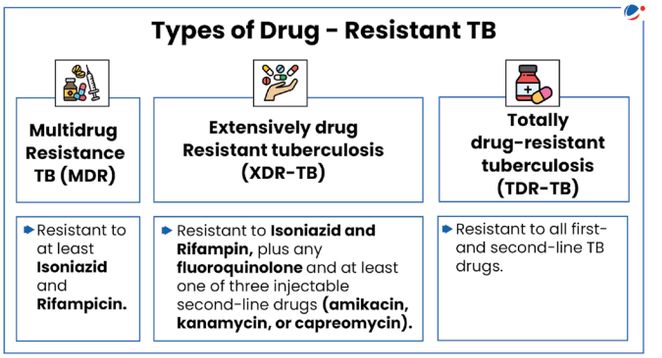
Ministry of Health and Family Welfare approved new BPaLM regimen consisting of four drugs: Bedaquiline, Pretomanid, Linezolid and Moxifloxacin.

About BPaLM regimen

- Introduced **under National TB Elimination Programme** to achieve goal of **ending TB** in India by 2025.
- **Cures drug-resistant TB in 6 months** (vs. 20 months for traditional MDR-TB).

About Tuberculosis (TB)

- An infectious disease that most often **affects lungs**.
- Caused by **bacillus Mycobacterium tuberculosis bacteria.**
- **Bacillle Calmette-Guerin (BCG) vaccine provides immunity** against TB.
- There were **25.52 lakh notified TB patients** in 2023 **(India TB Report 2024)**.
- **Other Key Initiatives:** Pradhan Mantri TB Mukt Bharat Abhiyan, Ni-kshay Mitra, and Nikshay Poshan Yojana.
- **Challenges:** Sub-optimally regulated private healthcare (irrational drug use), slow/unreliable conventional diagnosis, comorbidities (HIV, diabetes), and social stigma.



Conclusion

Collaborations with pharmaceutical and AI firms can boost early detection and treatment efficiency. Community involvement, social media outreach, and advocacy efforts can further promote timely diagnosis and care-seeking behaviour.

4.10.3. NEGLECTED TROPICAL DISEASES (NTDS)

Why in the News?

WHO published report titled Global report on Neglected Tropical Diseases 2024 which target reducing people needing interventions by 90% by 2030.

Neglected Tropical Diseases (NTDs)

- **These are a diverse group** of diseases caused by a **variety of pathogens** (including viruses, bacteria, parasites, fungi and toxins).
- **It is** called **Neglected** " due to absence from global health agenda, low funding, and stigma.
- **India:** It has the world's largest **absolute burden of at least 10 major NTDs**. About **40%** of people requiring interventions against NTDs in India.

Why eliminating NTDs is important?

- **Affecting large Population:** Over **1 billion** people globally.
- **Socio-economic Impact:** Eliminating NTDs by 2030 would save over **$342 billion** in healthcare costs.
- **Affecting Gender Equality:** For E.g. Female genital schistosomiasis affects an estimated 56 million women.
- **High returns on investment** ($25 benefits per $1 invested).

Challenges in handling NTDs

- **Knowledge gaps** hinder development of better NTD diagnostics, treatments, and vaccines.
- **Weak health systems** struggle to restore NTD services to pre-COVID-19 pandemic levels.
- **Limited surveillance** led to NTD underdiagnosis and underreporting, hampering strategic planning.
- **Unpredictable funding** disrupts medicine distribution, hindering demand forecasting and supply planning.
- **Rising temperatures** altering the spread of vector-borne diseases (WHO).

Steps Taken to control NTDs

- **Global:** Global NTD Annual Reporting Form (GNARF), Global vector control response (GVCR) 2017-2030, and Kigali declaration on NTDs (2022).
- **India:** National Vector Borne Disease Control Programme (NVBDCP), and National Programme for Control of Blindness.

Key recommendations of Global report on neglected tropical diseases 2024

- **Pillar 1: Accelerate Action:** Reduce disease burden (incidence, disability, death).
- **Pillar 2: Cross-Cutting Approaches:** Integrate and mainstream NTD services across programmes.
- **Pillar 3: Transform Models:** Promote country ownership and realign stakeholder roles.
- **Reposition NTDs**: Link with global health/emergency efforts, One Health, and climate priorities.

Conclusion

Overall, need a comprehensive approach that includes veterinary public health, improved water and sanitation, expanded vaccine access, food safety measures, vector control, and effective communication strategies to eliminated NTDs.

4.10.4. RARE DISEASES

Why in the News?

CDSCO approves **first anti-complement therapy for rare diseases.**

What are Rare Diseases?

- **WHO** defines rare disease as often debilitating lifelong disease or disorder with **a prevalence of 1 or less, per 1000 population.** For E.g. Fanconi Anaemia, Osteopetrosis etc.
- **India:** 63 Rare Diseases **are listed under National Policy for Rare Disease 2021 (NPRD, 2021).**

Classification of Rare Diseases in India (as per NPRD 2021)		
Group 1:	**Group 2**	**Group 3**
◆ **Amenable to one-time curative treatment** (e.g., Fanconi Anaemia).	◆ **Long-term treatment with lower costs/documented benefits** (e.g., Phenylketonuria).	◆ **Definitive treatment available but high cost/lifelong therapy challenges** (e.g., Gaucher Disease).

Initiatives taken to tackle rare diseases in India

- **National Policy for Rare Diseases, 2021**: Aims to lower incidence and prevalence of rare diseases.
- **Rashtriya Arogya Nidhi:** Provides financial assistance for poor patients suffering from rare disease.
- **Exemption on GST and Basic Customs Duty** on drugs imported for Rare Diseases for individual use.
- **Drugs and Clinical Trials Rules, 2019, CDSCO** has waived off local clinical trials for new drugs for rare diseases that have already been approved in countries like the United States, United Kingdom, Japan, etc.

Issues in managing Rare Diseases in India

- **Limited clinical trials**: Less than 0.1% of global clinical trials have site in India.
- **Lack of definition:** India currently lacks sufficient epidemiological data for a **standard definition.**
- **Underutilization of funds by CoEs**: Over ₹47 crore of the ₹71 crore allocated for financial assistance.
- **Limited treatment options:** 95% rare diseases have no approved treatment.

Way forward

- **Establish National Fund for Rare Diseases (NFRD).**
- **Create dedicated Fast Track approval process** for rare disease drugs and therapy.
- **Enable Corporate Social Responsibility (CSR) contribution** by companies, including Public Sector Undertakings by adding Donations for rare diseases in Schedule VII of the Companies Ac.
- **Establish hospital-based National Registry.**

Conclusion

Rare diseases demand greater awareness, early diagnosis, and equitable access to care. Through policy support, research, and global collaboration, we can improve outcomes and bring hope to affected individuals and families.

5. MISCELLANEOUS

5.1. PRESSURIZED HEAVY WATER REACTOR (PHWR)

Why in the News?

North India's first nuclear power project will be established in Gorakhpur, Haryana with two PHWR units (2800 MW) will be established.

About PHWR

- A **PHWR** uses **Heavy Water (D_2O)** as both coolant and moderator, with **natural uranium** as fuel.
  - **D_2O** slows neutrons effectively and has low absorption probability.
- **India's PHWR Development:** First **220 MW reactor** built at **Rajasthan Atomic Power Station (RAPS-1)**.
  - After **Pokhran-1 (1974)**, Canada withdrew support, leading India to **indigenously develop and standardize** the 220 MW PHWR design.

Fast Breeder Reactor (FBR)

- India's first FBR (500 MWe) commissioning by 2026 at **Kalpakkam (TN).** Marks beginning of 2nd stage of nuclear program.

About Fast Breeder Reactor

- **Genesis**: In 2003, government established **Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI)** to construct and operate **Prototype Fast Breeder Reactor (PFBR)**.
  - Earlier **first stage** was implemented by **Nuclear Power Corporation of India Limited (NPCIL).**
- **Significance of FBR:** Paves way for 3rd stage (Thorium-232 to Uranium-233 fuel), Technological Advancement (India 2nd country with commercial FBR), Reduced Nuclear Waste, and Utilization of Thorium Reserve.

5.2. THORIUM BASED REACTOR

Why in the News?

World's first thorium molten salt nuclear power station will be launched in Gobi Desert by China in 2025. Instead of Uranium, this nuclear power station uses **thorium as fuel.**

Thorium as a Fuel

- Thorium, a **naturally occurring element with radioactivity**, is found at trace levels in soil, rocks, water, plants and animals.
- Due to its physical characteristics, thorium **cannot be used directly to produce nuclear energy**. It has to be first converted to **U-233 in a nuclear reactor**.

Significance of Thorium based reactors

- **Abundant Supply** unlike Uranium. In India, **Kerala and Odisha** have rich reserves of **monazite**, which contains **about 8 – 10% thorium.**
- Monazite is also prominent in **Andhra Pradesh, Tamil Nadu, West Bengal and Jharkhand**.
- **Chemically safe,** due to higher melting point, better thermal conductivity, better fuel performance characteristics, chemical inertness and stability.
- **Environmentally safe,** generates lesser toxic and short-lived radioactive wastes.

Conclusion

With abundant thorium reserves and superior safety features, these reactors present a promising alternative to traditional uranium-based systems.

5.3. SMALL MODULAR REACTORS (SMRS)

Why in the News?

Union Budget 2024-25 announced that **Centre will partner with private sector** to develop **Bharat Small Reactors (BSRs).**

About Bharat Small Reactors (BSRs).

- **BSRs are aligned** with global trends where **Small Modular Reactors (SMRs).**
- **Unlike SMRs,** which are an entirely new concept involving **factory-made, easily assembled reactors, BSRs** are based on India's existing **Pressurized Heavy Water Reactor technology.**
- **They Can enhance** nuclear energy share **(currently 1.6%).**

What are Small Modular Reactors (SMRs)?

- **Definition:** Power capacity of **up to 300 MW (e) per unit** (1/3rd of traditional reactors).
- **Small**: Physically a fraction of the size of a conventional nuclear power reactor.
- **Modular:** Making it possible for systems and components to be factory-assembled and transported.
- **Reactors:** Harnessing nuclear fission to generate heat to produce energy.

Significance of SMR Nuclear Energy

- **Compact & Safe**: Passive safety systems reduce reliance on external power and pumps.
- **Versatile Use**: like seawater desalination (e.g., South Korea's SMART).
- **Factory-built**: Modular design allows easy transportation and quicker site assembly (e.g., NuScale).
- **Remote Operation**: e.g., Russia's Akademik Lomonosov.
- **Scalable**: Multiple modules can be installed at a single site for flexible power generation.

Concerns with SMRs

- **Commercial Risks**: Profit-driven private sector may compromise on safety.
- **Passive System**: Safety features may fail post-accident (U.S. Nuclear Regulatory Commission caution).
- **High Costs**: Smaller plants less cost-effective per MW than larger ones.
- **Waste Management**: Generates same level of radioactive waste per unit as large reactors.
- **Fuel Efficiency**: some need expensive high-assay low enriched uranium or HALEU fuel.

Conclusion

By offering scalable clean energy solutions with enhanced safety features, SMRs can play a vital role in meeting growing energy demands and reducing carbon emissions.

5.4. TOKAMAK REACTORS

Why in the News?

World's biggest nuclear fusion project, ITER completed its central magnet system; India played critical role in building components.

About Tokamak reactor

- **Term** "tokamak" comes from a Russian acronym that stands for "toroidal chamber with magnetic coils".
- **Purpose:** The **tokamak** is an experimental machine designed to harness the energy of fusion.
- **Working:** Inside a tokamak, fusion plasma is created and confined by strong magnetic fields.
  - **Plasma** is a **fundamental state of matter** along with **solids, liquids and gases.**
- **Energy to electricity:** The energy produced through the **fusion of atoms in the plasma** is absorbed as heat in the walls of the vessel.
  - **Just like a conventional power plant,** a fusion power plant will use this heat to produce steam and then electricity **by way of turbines and generators.**
- **Key Components: Torus** (donut-shaped chamber), **Magnetic coils** (toroidal and poloidal for magnetic 'cage'), and **Central solenoid (**A magnet that carries electric current).

About International Thermonuclear Experimental Reactor (ITER)

- **It is an international collaboration** (30+ countries including EU, China, India, Japan, Korea, Russia, US), located in Southern France.
- **Objective:** Demonstrate fusion viability (abundant, safe, carbon-free energy).
  - EU contributes 45% of cost; others 9%.
- **India joined** in 2005.
- **Institute for Plasma Research in Ahmedabad** Ahmedabad is lead Indian institution.

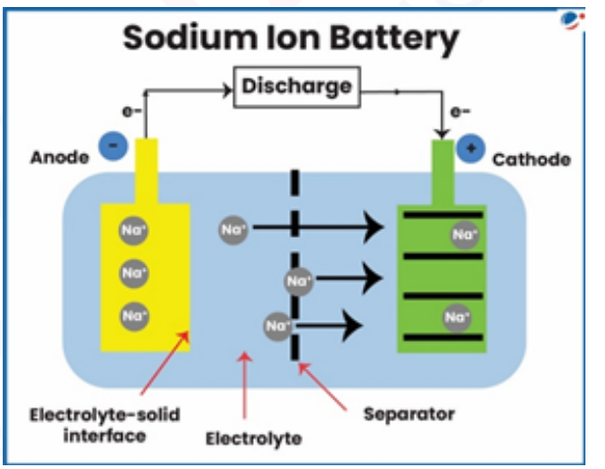
Conclusion

However **alternative laser fusion based on inertial confinement** is emerging as a viable alternative. In Toto global pursuit of practical nuclear fusion, possess unique advantages toward **achieving sustainable energy.**

5.5. SODIUM-ION BATTERY

Why in the News?

Research team developed a super-fast charging sodium-ion battery (80% in 6 minutes, 3000+ charge cycles).



About Sodium-Ion Battery (SIB)

- **Definition**: SIBs are a **type of rechargeable battery** similar to lithium batteries, but carry the charge using sodium ions (Na+) instead of lithium ions (Li+).

How Sodium-Ion Batteries (SIBs) Work?

- **During discharge**: Sodium ions move from **anode** (negative electrode) to **cathode (positive electrode)**, which hosts ions and undergoes **reduction**.
- **These ions travel through an electrolyte** (an electrical conductor) that enables the flow of current by creating a potential difference.
- **During Recharge:** Sodium ions return to the anode.

Advantages of Sodium-Ion Batteries (SIBs) Compared to Lithium-Ion Batteries (LIBs)

Parameter	Sodium-Ion Batteries (SIBs)	Lithium-Ion Batteries (LIBs)
Cost	15–20% lower; sodium is cheaper	Higher due to expensive lithium compounds
Supply Chain	Decentralised; sodium is abundant worldwide	Concentrated; e.g., China processes 60% lithium
Temperature Range	Better suited for wider temperature variations	Less tolerant to extreme temperatures
Safety	Can be shipped at zero voltage; lower fire risk	Requires precautions due to fire hazards

Conclusion

With advancements like ultra-fast charging and long cycle life, SIBs are emerging as strong contenders for applications in energy storage and electric mobility.

5.6. HYPERLOOP TECHNOLOGY

Why in the News?

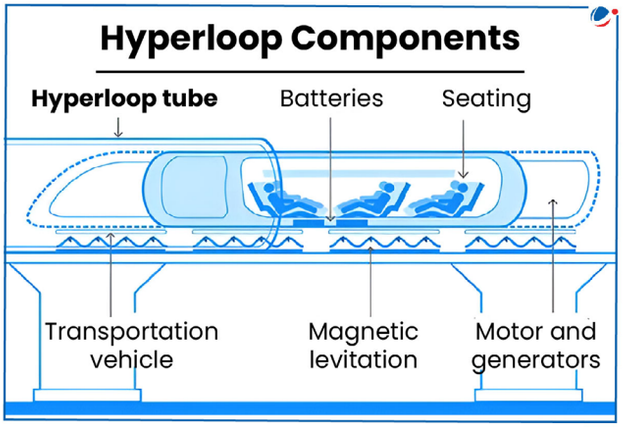
IIT Madras and TuTr (startup) completed a 410-meter Hyperloop test track in India.

What is Hyperloop Technology?

- **Proposed by Elon Musk** (2013), builds on "gravity vacuum tube" concept.
- **Functioning:**
  - **Magnetic levitation (maglev) system** uses magnets to hover/propel pods in a low-pressure tube with vacuums.
  - **Theoretical speed:** 1,200 km/h. Aims for time-space shrinkage, increasing city accessibility. .
- **Advantages**: High Speed (>1000 km/h), Driverless, On-Demand (10-30 sec intervals), Less Invasive (easier tunnels), Cuts Emissions (2-3x more efficient, uses maglev/low-pressure, stores electricity).

Issues with Hyperloop technology

- **High Costs**: ~$25–$27 million per mile (excluding land costs) as per NASA.
- **Safety Concerns**: Fire inside pods is a major risk despite fire-resistant tubes.
- **Vacuum Maintenance**: Energy-intensive and challenging over long distances.
- **Acceleration Impact**: Lateral/vertical acceleration >2 m/s^2 can cause motion sickness.
- **Infrastructure Demand**: Needs long, straight, stable tracks are difficult to construct.



Conclusion

As India enters the global Hyperloop race with initiatives like the IIT Madras test track, fostering collaboration between academia, startups, and policymakers will be key to realizing its full potential.

5.7. DESALINATION TECHNOLOGIES

Why in the News?

IIT Bombay scientists developed a lotus leaf-inspired hydrophobic graphene-based solar evaporator for efficient water desalination, offering a breakthrough solution to the global freshwater crisis.

Status of Freshwater Crisis: 71% of Earth's surface is water, but only 3% is freshwater, and only 0.06% is easily accessible.

Desalination Technologies and Processes

Aspect	Thermal Technology	Membrane Technology
Concept	Heats water, collects vapor; for seawater desalination to pure water	Filters through membranes; for brackish water
Processes	Flash, Multi-Effect, Vapor Compression	Electrodialysis, Reverse Osmosis
Merits	Cuts high salinity; uses less electricity	Eco-friendly, smaller footprint
Demerits	Costly, uses fossil fuels, scaling issues	Fouling, high maintenance, incomplete TDS removal
Example	**Low Temperature Thermal Desalination** in Lakshadweep	Nemmeli RO Plant, Tamil Nadu

Conclusion

Moving forward, scalable deployment, supportive policy frameworks, and continued research will be crucial to ensure equitable access to clean water across regions.

5.8. LIGHT SUPERSOLID

Why in the News?

For the first time scientists of Italy's National Research Council have **made super solid from light.**

About Super solid

- **Definition:** It is a **rare state of matter** that **exhibits both solid-like structure and frictionless flow.**
- **Initial Research: First predicted in the 1960s**, Super solid were demonstrated in **2017** using **ultracold Bose–Einstein Condensates (BEC)**.
- **Current Research:** The new research used a **novel mechanism** that relies on the properties of **"polariton" systems**.
  - **Polaritons** are formed by **coupling light and quasiparticles like excitons** through strong electromagnetic interactions.
  - **Quasiparticles** are mathematical construct which **treat elementary excitations in solids**, like spin waves, **as particles**.
- **Significance of Converting Light into Supersolid**: Developing more stable qubits for quantum computing, revolutionizing optical devices/photonic circuits, and advancing material science/energy use.

Conclusion

The creation of a light-based super solid marks a remarkable breakthrough in quantum physics, opening new pathways in the manipulation of light and matter.

5.9. VIGYAN DHARA SCHEME

Why in the news?

Union Cabinet approved continuation of three umbrella schemes into 'Vigyan Dhara' to enhance India's R&D ecosystem.

About Vigyan Dhara Scheme

- **Nodal Ministry:** Ministry of Science and Technology.
- **Key objective:** To promote **S&T capacity building** as well as **research, innovation and technology development** towards strengthening the Science, Technology and Innovation ecosystem in the country.
- **Type:** Central Sector Scheme
- **Tenure:** From 2021-22 to 2025-26 (15th finance Commission period)
- **Potential Benefits:** Building critical human resource pool, expanding R&D base (Full-Time Equivalent (FTE) researcher count), and enhancing women's participation in S&T (gender parity).

3 Primary Components Of Vigyan Dhara Scheme

Science and Technology Institutional and Human Capacity Building: Strengthening existing scientific institutions

Research and Development: To support research activities in diverse fields, including:

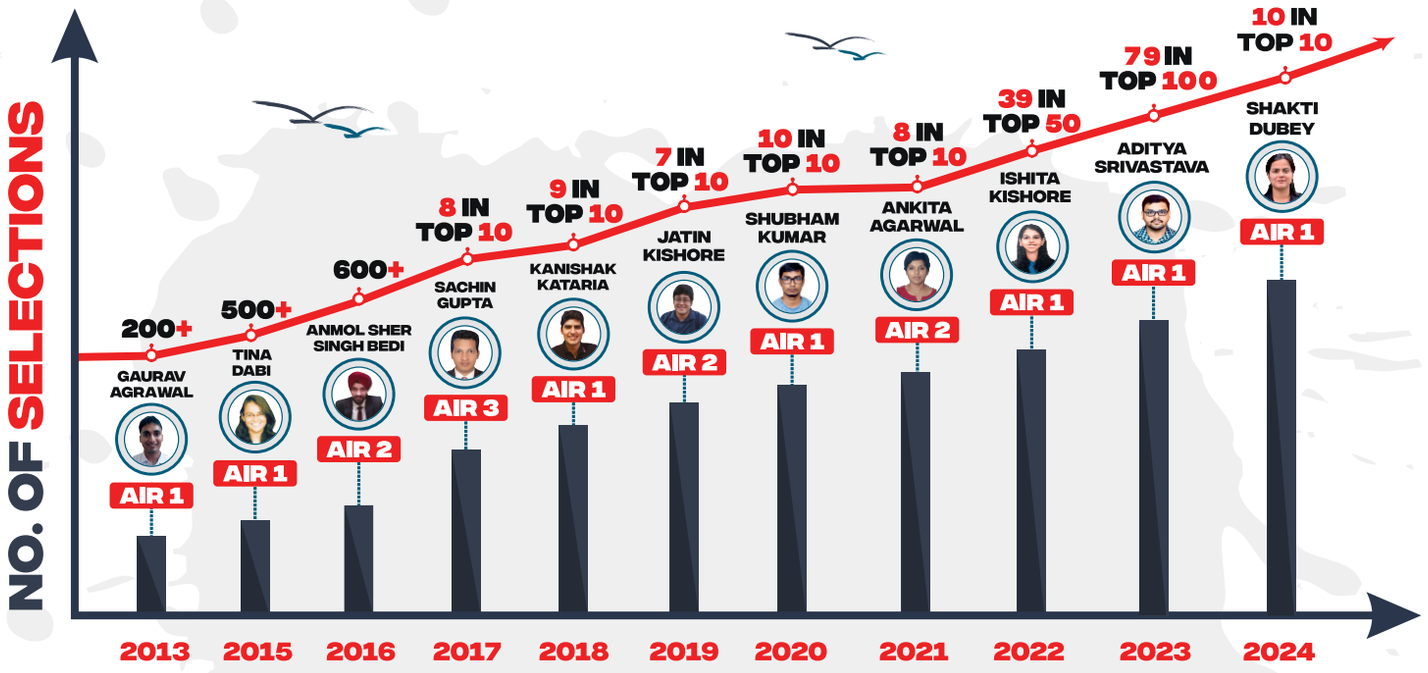
Innovation, Technology Development, and Deployment: To foster innovation and the development of new technologies

Conclusion

The Vigyan Dhara Scheme represents a strategic step toward strengthening India's scientific and technological capabilities. Its focus on gender parity, international partnerships, and indigenous innovation further reinforces India's vision of becoming a global leader in science and technology.

VISIONIAS
INSPIRING INNOVATION

OUR ACHIEVEMENTS



LIVE/ONLINE
Classes Available
www.visionias.in

Foundation Course
GENERAL STUDIES
PRELIMS cum MAINS 2026, 2027 & 2028

DELHI : 30 JULY, 8 AM | 7 AUGUST, 11 AM | 14 AUGUST, 8 AM | 19 AUGUST, 8 AM
22 AUGUST, 11 PM | 22 AUGUST, 11 AM | 26 AUGUST, 8 AM | 30 AUGUST, 8 AM

GTB Nagar Metro (Mukherjee Nagar): 10 JULY, 8 AM | 29 JULY, 6 PM

हिन्दी माध्यम 7 अगस्त, 2 PM

AHMEDABAD: 12 JULY | **BENGALURU: 22 JULY** | **BHOPAL: 27 JUNE** | **CHANDIGARH: 18 JUNE**
HYDERABAD: 30 JULY | **JAIPUR: 5 AUG** | **JODHPUR: 10 AUG** | **LUCKNOW: 22 JULY** | **PUNE: 14 JULY**

फाउंडेशन कोर्स सामान्य अध्ययन 2026

- प्रारंभिक, मुख्य परीक्षा और निबंध के लिए महत्वपूर्ण सभी टॉपिक का विस्तृत कवरेज

DELHI : 7 अगस्त, 2 PM | **JAIPUR : 20 जुलाई** | **JODHPUR : 10 अगस्त**

Scan the QR CODE to download VISION IAS App. Join official telegram group for daily MCQs & other updates.

/visionias.upsc | /c/VisionIASdelhi
/c/VisionIASdelhi | /t.me/s/VisionIAS_UPSC

DELHI: GMMR 33, Pusa Road, Near Karol Bagh Metro Station, Opposite Pillar No. 113, Delhi – 110005 **CONTACT:** 8468022022, 9019066066

AHMEDABAD | BENGALURU | BHOPAL | CHANDIGARH | GUWAHATI | HYDERABAD | JAIPUR | JODHPUR | LUCKNOW | PRAYAGRAJ | PUNE | RANCHI

Heartiest Congratulations to all Successful Candidates

10 in **TOP 10** Selections in **CSE 2024** from various programs of **Vision IAS**

Shakti Dubey

Harshita Goyal

Dongre Archit Parag

Shah Margi Chirag

Aakash Garg

Komal Punia

Aayushi Bansal

Raj Krishna Jha

Aditya Vikram Agarwal

Mayank Tripathi

79 Selections in **TOP 100** in **CSE 2023**

Aditya Srivastava

Animesh Pradhan

Ruhani

DELHI

GMMR ENQUIRY & CLASSROOM CENTRE
33, Pusa Road,
Near Karol Bagh Metro Station,
Opposite Pillar No. 113,
Delhi - 110005

MUKHERJEE NAGAR CENTER
Plot No. 857, Ground Floor,
Mukherjee Nagar, Opposite Punjab & Sindh Bank, Mukherjee Nagar

GTB NAGAR CENTER
Classroom & Enquiry Office,
above Gate No. 2, GTB Nagar Metro Building, Delhi - 110009

FOR DETAILED ENQUIRY
Please Call:
+91 8468022022,
+91 9019066066

enquiry@visionias.in | /c/VisionIASdelhi | /visionias.upsc | /vision _ias | VisionIAS_UPSC

AHMEDABAD | BENGALURU | BHOPAL | CHANDIGARH | DELHI | GUWAHATI | HYDERABAD | JAIPUR | JODHPUR | LUCKNOW | PRAYAGRAJ | PUNE | RANCHI